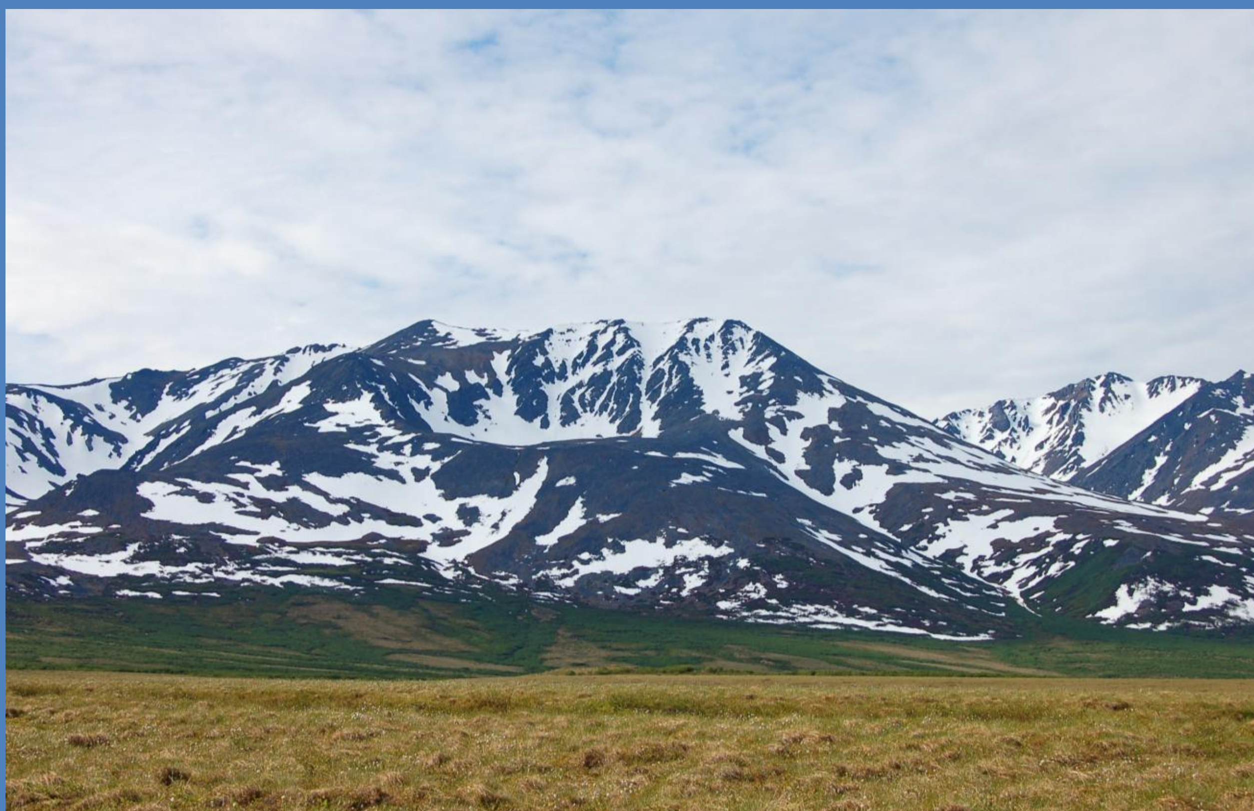
SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS
RAPID ECOREGIONAL ASSESSMENT

FINAL REPORT II-3-c



REA Final Report for

U.S. Department of the Interior
Bureau of Land Management
Rapid Ecoregional Assessments

October 2012

It is the mission of the Bureau of Land Management to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations.

SUBMITTED TO

Scott Guyer, Ecoregional Assessment Project Manager
Department of the Interior
Bureau of Land Management
222 West 7th Avenue, Suite 13
Anchorage, AK 99513

SUBMITTED BY

NatureServe
4600 North Fairfax Drive, 7th Floor
Arlington, VA 22203

COVER PHOTO

Kigluiak Mountains, Alaska. Photo by Dr. Matt Carlson, Alaska Natural Heritage Program.

TITLE PHOTO

Fall colors in the Sinuk River valley near Glacial Lake, Kigluaik Mountains. Photo by Scott Babcock.

REA Final Report for

U.S. Department of the Interior Bureau of Land Management Rapid Ecoregional Assessments

October 2012

SEWARD PENINSULA – NULATO HILLS – KOTZEBUE LOWLANDS

RAPID ECOREGIONAL ASSESSMENT

CO-PRINCIPAL INVESTIGATORS

Patrick Crist & Patrick Comer

SUGGESTED CITATION

M. Harkness, M. Reid, N. Fresco, S. Martin, H. Hamilton, S. Auer, S. Marchenko, J. Bow, I. Varley, P. Comer, P. Crist, and L. Kutner. *Seward Peninsula – Nulato Hills – Kotzebue Lowlands Rapid Ecoregional Assessment Report.* Prepared for the U.S. Department of the Interior, Bureau of Land Management.

TEAM MEMBERS

NATURESERVE
Patrick Crist
Patrick Comer
Marion Reid
Mary Harkness
Jacquie Bow
Ian Varley
Lynn Kutner

NATURESERVE – TECHNICAL STAFF
Keith Shulz
Mark Hall
Jon Hak
Gwen Kittel
Suzanne Young
Kristin Snow
Mary Russo

UNIVERSITY OF ALASKA PROGRAMS: ALASKA NATURAL HERITAGE PROGRAM
Monica McTeague
Tracey Gotthardt
Becky Shaftel
Tina Kuo

ALASKA NATURAL HERITAGE PROGRAM – TECHNICAL STAFF
Dan Bogan
Kelly Walton

SCENARIOS NETWORK FOR ALASKA AND ARCTIC PLANNING
Nancy Fresco
Amy Breen
Scott Rupp
Tom Kurkowski
Mark Olson
Matthew Leonawicz
Piia Kortsalo

INSTITUTE FOR SOCIAL AND ECONOMIC RESEARCH
Stephanie Martin
Katherine Jackstadt
Suzanne Sharp
Marie Lowe

SOUND SCIENCE, LLC
Healy Hamilton
Stephanie Auer
David Maddox
David Braun

UNIVERSITY OF ALASKA, FAIRBANKS – GEOPHYSICAL INSTITUTE PERMAFROST LAB
Sergey Marchenko

MARGARET J. KING & ASSOCIATES
Meg King

CONTRIBUTORS

BLM
Paul Krabacher
Scott Guyer
Jolie Pollet
Shelly Jacobsen
Karen Prentice
Jason Taylor
Dave Howell
Stacie McIntosh
Tim Hammond
Bob Schneider
John Erlich, Sr.
Travis Haby
Cindy Hamfler
Douglas Ballou
Jim Fincher
Karen Kelleher
Steve Hartmann
Ted Murphy

USFWS
Karen Murphy
Anne Orlando
LeeAnne Ayres
Greg Balogh
Tina Moran
Charisa Morris
Jimmy Fox
Kristine Sowl
Melissa Gabrielson
Thomas Doolittle

NPS
Jeanette Pomrenke
Jim Lawler
Ken Adkisson
Peter Neitlich

NOAA
James Partain
Amy Holman

ALASKA DEPARTMENT OF FISH AND GAME
Doug Vincent-Lang
Dan Reed
John Burr
John Chythlook
Peter Bente

ALASKA DEPARTMENT OF NATURAL RESOURCES
Tom Crafford
Samantha Carroll
Kyle Smith

UNIVERSITY OF ALASKA
Bob Bolton
Tobias Schwoerer
Yuri Shur
Vladimir Romanovsky
Sarah Trainor

ARCTIC RESEARCH CONSORTIUM OF THE U.S.
Helen Wiggins
Julie Griswold
Susan Fox

NORTHWEST ARCTIC BOROUGH
Charlie R. Gregg
Lincoln Saito
Noah Naylor
Ukallaysaaq Tom Okleasik

NOORVIK NATIVE COMMUNITY
Charlie Nazuruk
Lonnie Tebbits

NATIVE VILLAGE OF KOTZEBUE
Alex Whiting

CITY OF NOME
Eileen Bechtol

MANIILAQ ASSOCIATION
Paul Eaton

NANA REGIONAL CORPORATION
Bibianna Scott
Elizabeth Moore

USGS PEER REVIEWERS
Courtney Amundson
Tony DeGange
Colleen Handel
Dave Gustine
Mark Shasby
Natasha Carr
Steve Frenzel

Contents

Tables

Figures

Executive Summary

Rapid Ecoregional Assessments: Purpose and Scope

Working with agency partners, BLM is conducting rapid ecoregional assessments (REAs) covering approximately 450 million acres of public and non-public lands in ten ecoregions and combinations of ecoregions in the American West and Alaska. The goal of the REAs is to characterize ecological resource status, potential to change from a landscape viewpoint, and potential priority areas for conservation, restoration, and development. REAs are intended to serve BLM's developing ecoregional direction that links REAs and the BLM's Resource Management Plans and other on-the-ground decision-making processes. Ecoregional direction establishes a regional roadmap for reviewing and updating Resource Management Plans, developing multi-year work for identified priority conservation, restoration and development areas, establishing Best Management Practices for authorized use, designing regional adaptation and mitigation strategies, and developing conservation land acquisitions. While REAs produce information designed to be integrated into specific management processes, they are not decision documents and stop short of integrating the findings into management actions. The Bureau of Land Management (BLM) chose to retain responsibility for all aspects of integrating ecoregional assessments into management actions and decisions. The BLM requested the United States Geological Survey (USGS) to provide peer review for technical and scientific accuracy. Key components of the Seward Peninsula – Nulato Hills – Kotzebue Lowlands REA are described below.

Defining the Assessment Region

BLM provided specific criteria for delineating the geographic extent of REAs: the level III ecoregion delineation of the Commission for Environmental Cooperation and all 5th-level Hydrologic Units (HUCs) that intersect the ecoregion boundary. The resulting SNK ecoregion is shown in Figure 1-1. Including the buffer, it is approximately 60,000 miles^2 in size. BLM manages 43% of the ecoregion; native corporation lands comprise approximately 15% of the ecoregion.

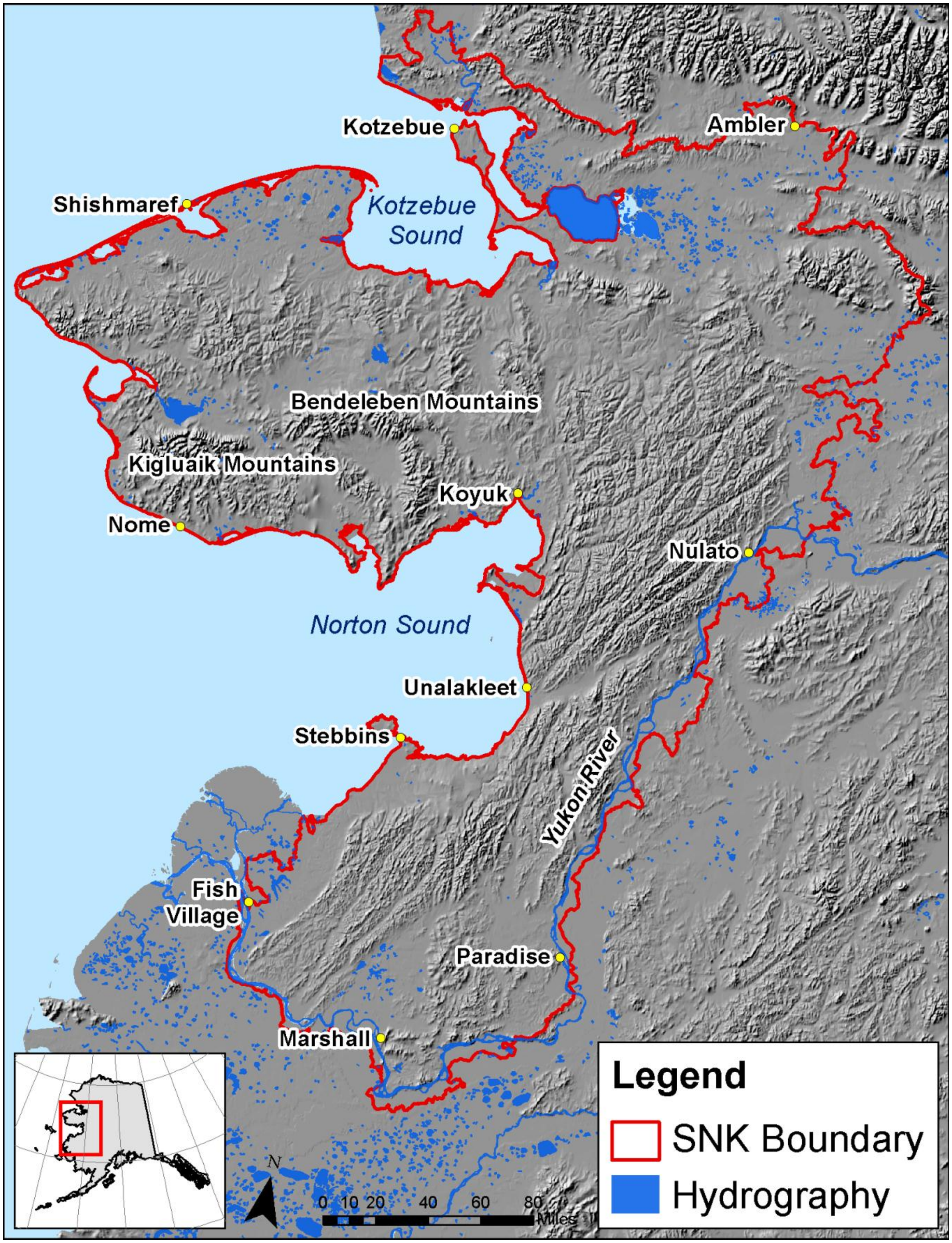
Management Questions

The basis of the assessment work in an REA is to answer management questions. A total of 57 management questions were assessed. Most management questions fall into these general categories:

- Where is it? (e.g., where are conservation elements?)
- Where does it coincide with other features? (e.g., where do conservation elements coincide with change agents?)
- Where and how might the conservation elements be affected by change agents, either now or in the foreseeable future?

There are several more specific and complex management questions, particularly characterizing the socioeconomic context and subsistence practices in the ecoregion. Some key results of the assessments are highlighted in this executive summary; primary management questions are treated in the main report but due to space limitations, additional questions are addressed in the appendices of the report. The Introduction chapter includes an overview for locating content within the report and appendices as well as a table summarizing where each management question is treated.

Figure 1-1. Ecoregion boundary (in red) for the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion.



Conservation Elements

A foundational component of REAs is "conservation elements," representing ecosystems, species, and other resources of management interest. Table 1 shows the breakdown of conservation elements for this ecoregion.

Table 1. Number of conservation elements by category.

Conservation Element Category	Number of Elements
Upland Ecosystems	13
Lowland Ecosystems	8
Aquatic Ecosystems	9
Coastal Ecosystems	2
Species Assemblages	3
Landscape Species	24
Local Species	29
Subsistence Species (includes subsets of both landscape and local species)	17

Change Agents

Change agents are those features or phenomena that have the potential to affect the size, condition, and landscape context of conservation elements. Four classes of change agents were included in the assessment: climate change, wildfire, development, and invasive species. Because it plays such a determining role in ecosystem function in this ecoregion, permafrost was also assessed. Change agents act differentially on individual conservation elements; while for some conservation elements they may have neutral or positive effects, they generally are expected to cause negative impacts. Change agents can impact conservation elements at their point of occurrence as well as off site. Individual change agents can also be expected to act synergistically with other change agents to have increased or secondary effects.

REA Products and Results

The following sections in the executive summary highlight key results of the REA. The body of the report includes a chapter containing a summary discussion of methods used to generate the results and a pair of chapters on current and projected future conditions in this ecoregion. Extensive appendices provide complete details on methods and data used and data products delivered to BLM contain further details in their metadata. A brief summary of *Key Limitations and Data Gaps* is provided at the end of the executive summary. Specific limitations are provided in the report chapters; users of the REA products should understand these limitations in order to appropriately apply these products.

Conservation Elements: Distribution and Status

The Alaska Natural Heritage Program compiled, modeled, or synthesized data to develop distributions for a large portion of conservation elements, while models of predicted habitat developed by the Alaska GAP program were used for most of the terrestrial species conservation elements. A scorecard approach was used to summarize the current ecological status of a given conservation element throughout its distribution in the ecoregion. Using this approach, indicators were chosen to provide a measurement for a limited set of **key ecological attributes**, or ecological drivers, for each conservation element. Given the rapid and regional nature of an REA, indicators that could be readily characterized from existing data were used. A landscape condition model was used for all conservation elements to estimate effects of direct human development (Figure 1-2). The landscape condition model used development change agents and ranked their proportional impact on the condition of the landscape at their point of occurrence and a distance away from it. For aquatic CEs, additional indicators such as the connectivity indicator were identified and evaluated as well (Figure 1-3).

Figure 1-2. Current landscape condition indicator based on development change agents (illustrated here without reference to CEs). The landscape condition model incorporates general landscape impacts at the point of the development footprint and a distance extending out from the footprint. The darkest green end of the color ramp indicates the most intact locations, while the reddest end are the most impacted. There is very little development impact in the SNK ecoregion, and it is almost entirely concentrated around the various human communities in the ecoregion, such as Nome and Kotzebue.

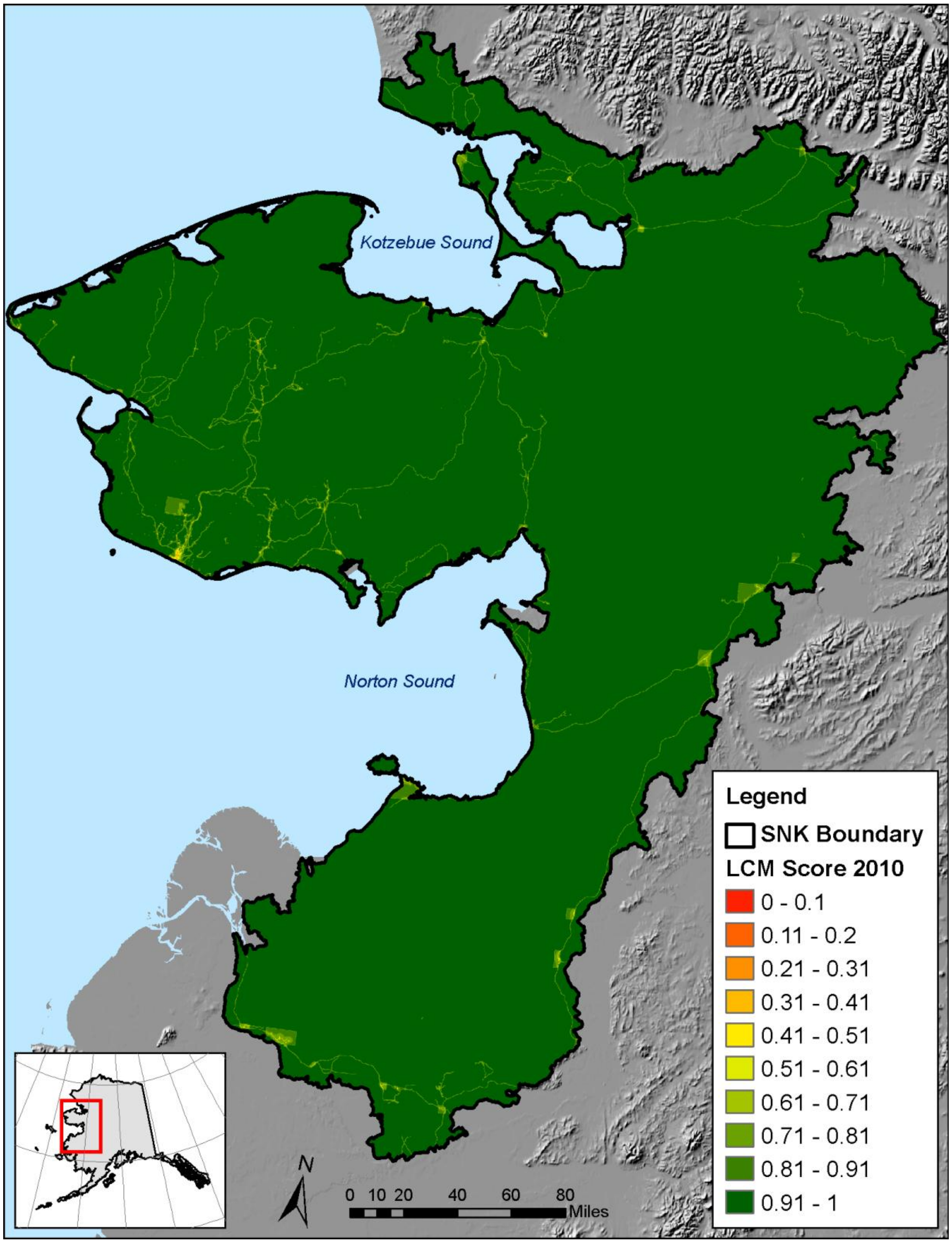
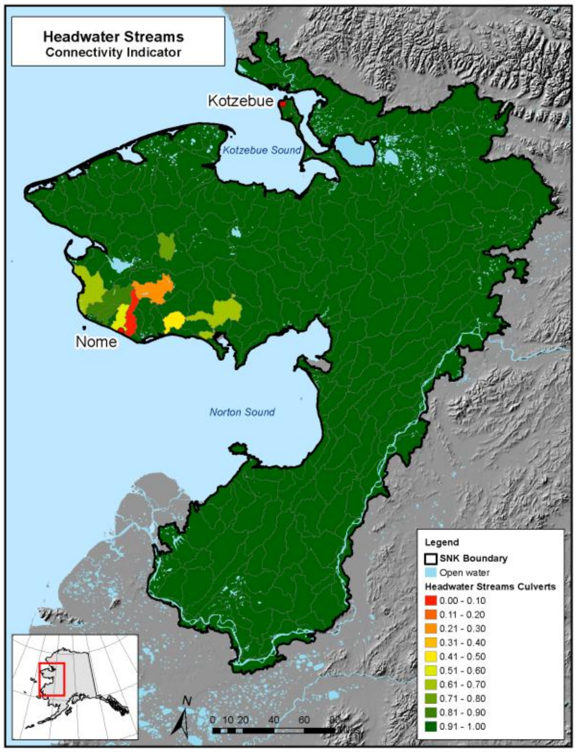


Figure 1-3. Ecological status assessment results for the connectivity (index of fish passage/culverts) indicator for the headwater streams CE throughout its distribution. The darkest green end of the color ramp indicates the areas with intact stream connectivity, while the reddest end indicates areas the most impacted by culverts. Roads are largely limited to the area around Nome; therefore, associated culverts and fish passage issues are concentrated in that area.



Among the terrestrial and aquatic CEs in this ecoregion, landscape condition is generally high across the vast majority of their distribution, without exception (even for narrowly distributed CEs). This reflects the very limited footprint of roads and other localized development change agents present in this remote and largely undeveloped ecoregion. What development impacts are present are largely associated with the human community footprints, particularly around Nome and Kotzebue.

Change Agents: Current and Future

Maps representing change agent distributions were compiled or derived from a number of sources and in most cases augmented with spatial modeling to derive expected distributions. Future distribution of change agents included maps of planned/potential distribution (e.g., proposed roads) or models (e.g., climate change, fire, permafrost).

Currently and into the future, climate change and its associated projected impacts on fire regimes and permafrost cover are by far the greatest management concerns in this ecoregion. Climate model projections for the 2020s for this REA indicate that a substantial amount of change has already taken place, and this is supported by other research (e.g., documentation of 10-km treeline shift on the Seward Peninsula by Lloyd et al. 2002).

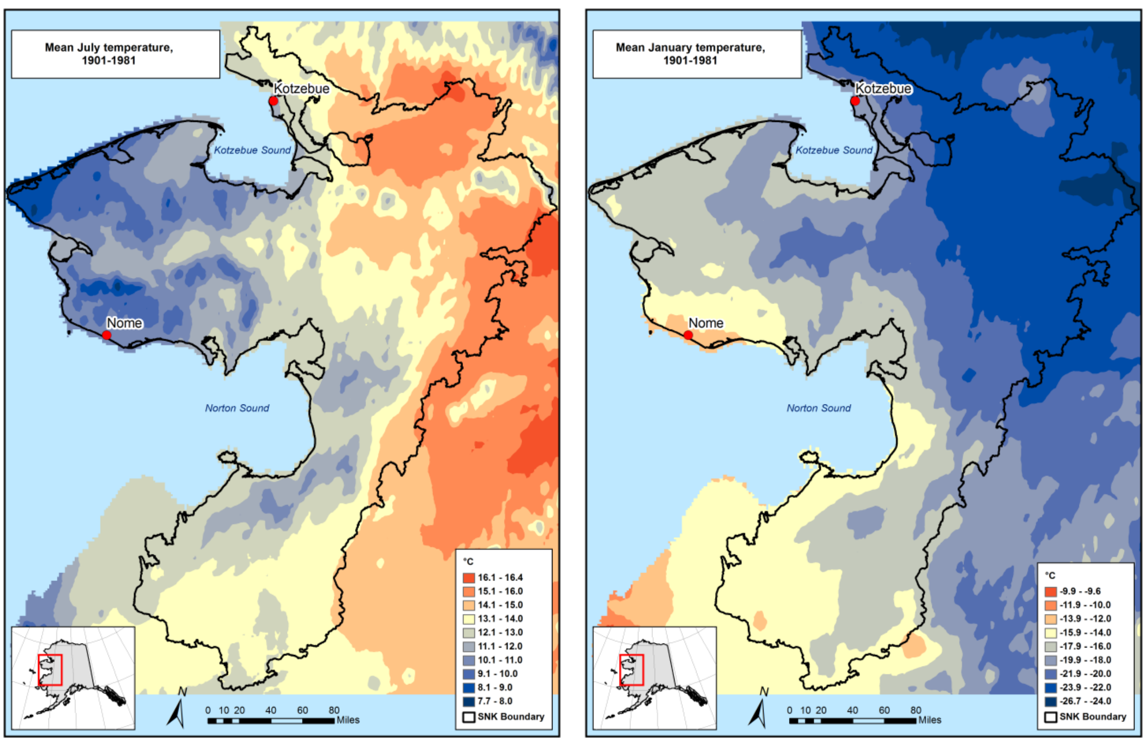
Climate: Current

Between 1901 and 1980, the period selected as a historical baseline, January temperatures (Figure 1-4) averaged between -9 and -21°C across the region with the warmest areas being along the coastlines, and the coldest areas being in the northeastern inland regions. In July this pattern is largely reversed (Figure 1-4), with the moderating effects of the ocean keeping coastal areas cooler, and inland areas having the highest mean temperatures. Both temperature and precipitation varied considerably from year to year across the 80-year historical reference period. This natural variability must be taken into account when considering ongoing and future climate trends.

Climate change impacts are already underway in the region. Reconstructions of vegetation change attributable to past warming show that spruce trees have been encroaching into tundra since the 1880s. Recent research shows that ongoing change in this area is toward increased shrubbiness.

Climate change effects are producing large-scale economic changes for the region; human communities, which are generally located along rivers or on coastlines, are at risk of erosion due to the combination of loss of permafrost and loss of shore-fast ice protecting infrastructure from storm events. One community, Shishmaref, has voted to relocate and selected a new site; other communities are considering relocation. Shaktoolik, Selawik, Deering, Golovin, St. Michael, and Unalakleet have all been identified by the Army Corps of Engineers as being at risk from erosion damage and will either need to be relocated or have major erosion projects in put place.

Figure 1-4. Historical mean temperatures for 80-year reference period (1901-1980), for January (left) and July (right).



Climate: Future Projections

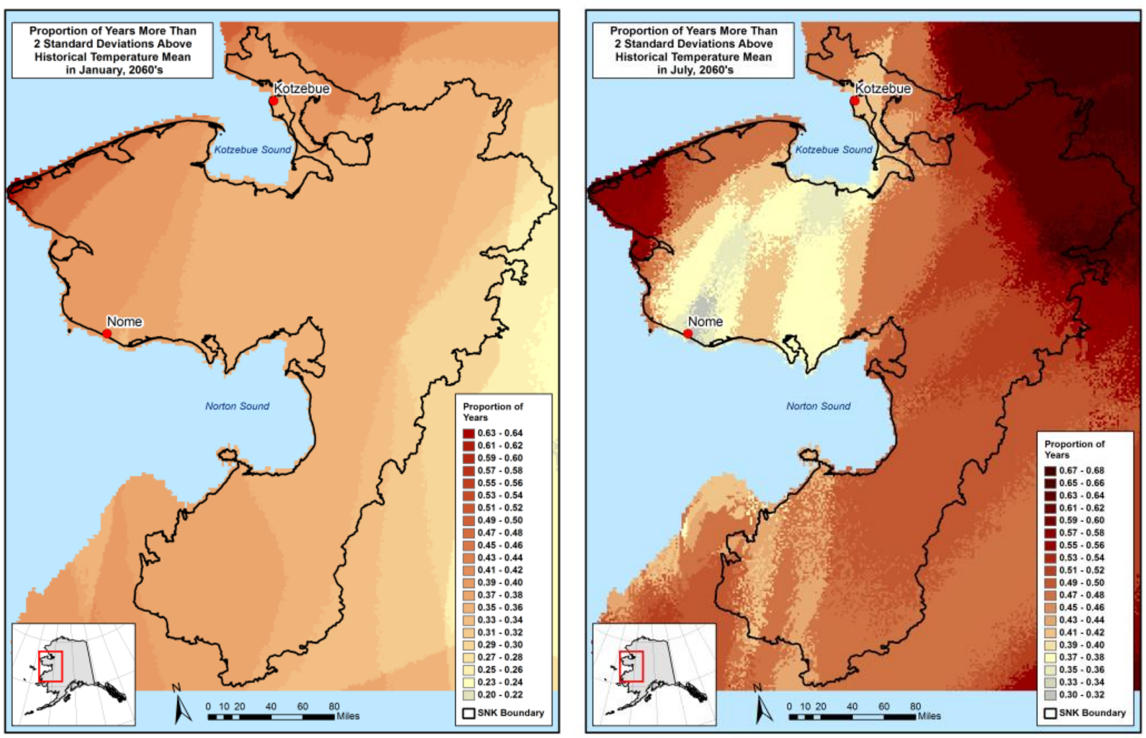
SNAP climate projections for the 2020s, 2050s and 2060s show a marked warming trend for all seasons, as compared to the baseline period (1901-1980). Projections also indicate an increase in precipitation, although certainty is lower, in part due to the greater natural variability in precipitation. By 2025, January temperatures are expected to increase by ~2°C in coastal areas and by ~3°C in upland and inland areas. By 2060, winter temperature shift is likely to be up to 8°C. Similar, although slightly less extreme changes are expected in summer conditions. Precipitation shifts are relatively subtle, with slight increases region-wide. Warmer temperatures may mean that less of this precipitation falls as snow. Increases in evapotranspiration may more than offset increases in precipitation, leading to an overall drying effect.

In order to evaluate whether future temperature and precipitation will be “abnormal” as compared to historical values, this assessment compared projected values to the mean and standard deviation for 1901-1980. This approach created a useful metric (Figure 1-5) for addressing the question of whether typical (average) future values are likely to be outside of the range of 97.5% of historical values (given that less than 2.5% of normally distributed data would be expected to be above the upper bounds of two standard deviations). For example, in the 2050s or 2060s, will a typical July be hotter than 97.5% of all historical Julys?

By the 2060s, models predict that at least a quarter of Januaries will be abnormally warm (>2 standard deviations above the historical 80-year average) across the entire SNK ecoregion, and that in the coastal regions of the Seward Peninsula, more than half of Januaries will be warmer than 97.5% of all historical Januaries.

The impacts of this change are likely to include forest species gaining territory at the expense of tundra species and encroachment by invasive species. In general, species with broader, more plastic habitat requirements may fare better than those with limited dispersal ability and narrow niches. With winter precipitation remaining the same or seeing slight increases, rain-on-snow events are likely to increase in frequency. Such events have a strongly adverse effect on caribou and reindeer.

Figure 1-5. Proportion of Januarys (left) and Julys (right) projected to fall above the normal range of temperature in the 2060s decade.



Permafrost: Current

Current permafrost conditions vary across the study area, with some areas of continuous permafrost to the north, and discontinuous permafrost to the south (Figure 1-6, left). Even in areas with mean annual ground temperature (MAGT) well below freezing, some microsites are permafrost free. Likewise, even in the warmest areas, permafrost may underlie cold microsites.

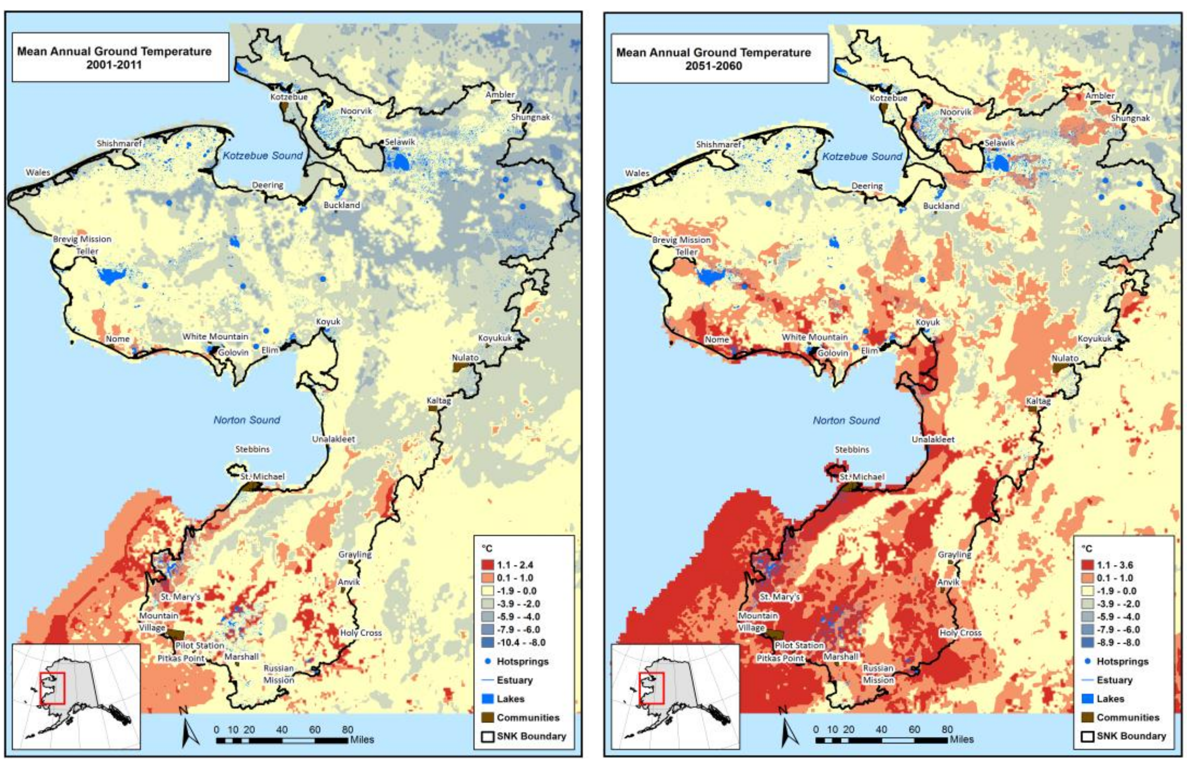
Permafrost in the SNK ecoregion is already undergoing change. Remote sensing imagery shows that in recent decades, the total surface area of lakes has decreased, although the number of lakes has increased. In lowland sites, trees began establishing in recent thermokarst areas of the tundra after 1920.

Permafrost: Future Projections

Permafrost model outputs provide a general picture of areas likely to undergo thaw and associated hydrologic changes. Permafrost is expected to undergo significant thaw across much of the SNK ecoregion as mean annual ground temperature at one meter depth rises from below 0°C to above 0°C (Figure 1-6, right) – although thaw at one meter does not equate to total permafrost loss.

Changes in hydrologic regime are likely in permafrost areas projected to undergo partial or total thaw. Permafrost thaw may accelerate shrubification and drying of soils. Permafrost thaw and its effects are particular to microsites, implying that managers must assess change on a case by case basis. Although it is likely that some lake drainage will occur as a direct result of permafrost loss, it is difficult to predict which ponds and lakes will be affected, or the timing of the change. Associated damage to water supply and other infrastructure could be severe. Along the coast, changes in the seasonality of frozen ground and shore-fast ice are already having profound effects, as thawed soils become subject to erosion; such effects will continue into the future.

Figure 1-6. Current (left) and projected future (right, for 2050s) mean annual ground temperature at 1 meter depth.

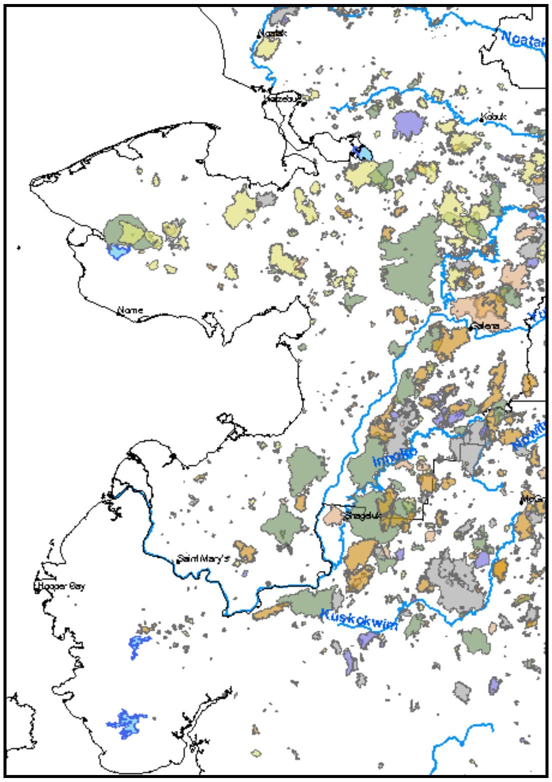


Fire: Current

Historically, fire has been far less common in the Seward Peninsula portion of the SNK ecoregion than in the interior boreal forest, with many areas remaining unburned over the past seventy years. However, large fires have occurred, particularly in more inland areas (Figure 1-7).

Recent decades have seen marked change in Arctic tundra ecosystems due to the interplay of climate change, wildfire, and disturbance by caribou and reindeer. These interdependent changes are all implicated in the observed significant reduction of terricolous lichen ground cover and biomass.

Figure 1-7. Fire history from 1940 to the present (http://fire.ak.blm.gov/predsvcs/maps.php)

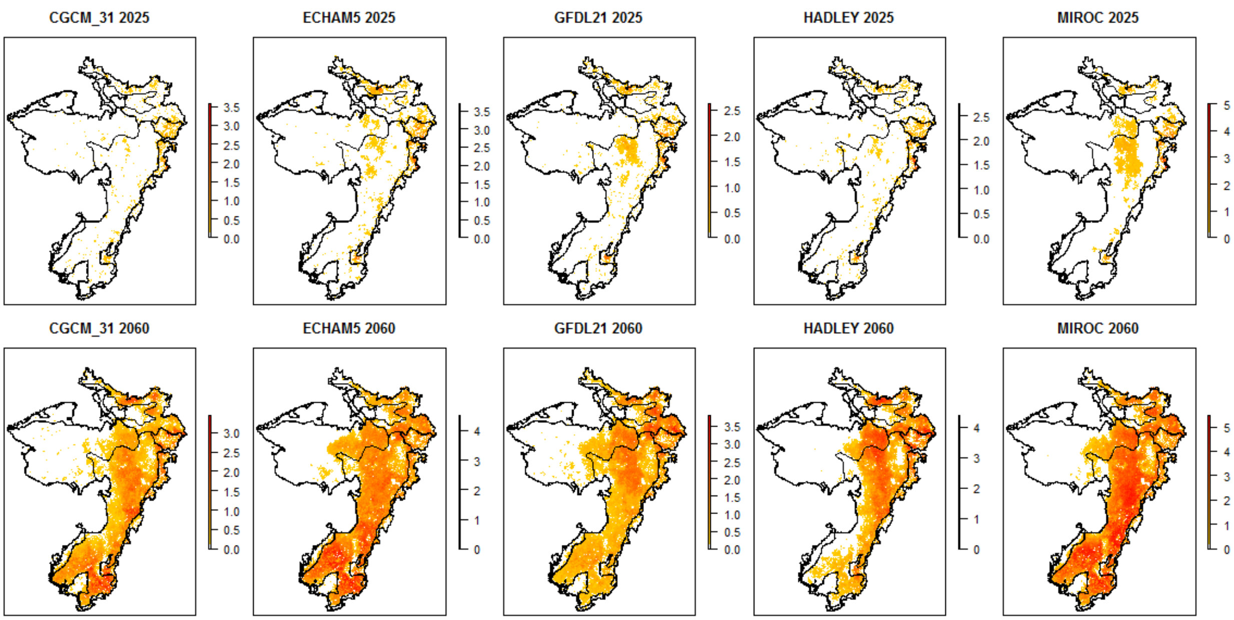


Fire: Future Projections

Despite difficulties calibrating the ALFRESCO model to deal with the shrubby/deciduous vegetation class prevalent in some areas of the SNK ecoregion, modeling results clearly indicate an increase in fire frequency across the future time period (2025 and 2060), with the annual probability of fire increasing to as much as 5% in some areas (Figure 1-8). More frequent tundra burning is very likely, and fire cycles in spruce forests will shorten.

Shorter fire cycles and more frequent burning in areas that previously saw little fire will result in an overall shift toward early successional vegetation. Species such as willow, birch, and aspen may gain precedence over late successional spruce in forested areas, and in tundra, faster-growing grasses may prevail over slower-growing lichens. Species that rely on early-succession vegetation (e.g., moose) are likely to gain a competitive advantage over those that require late-succession vegetation (e.g., caribou). Along rivers, fires can add large woody debris and nutrients to rivers immediately following severe burns, and burning along river banks can exacerbate erosion. For communities, the effects of fire include the threat of losing housing and infrastructure as well as disruption of travel and altered subsistence opportunities. Increases in fire frequency may accelerate the thaw of permafrost in the region.

Figure 1-8. Mean annual probability of fire calculated using downscaled data for five Global Circulation Models (averaged across 60 model replicates and 15 years) for 2010-2025 (top) and 2045-2060 (bottom). Scale bar to the right of each graphic shows annual percent risk or probability that a given pixel will burn.



Socioeconomic and Subsistence: Current and Future Conditions

The SNK ecoregion is home to approximately 18,000 people; Nome and Kotzebue are the two largest communities, with 3,600 and 3,200 people respectively. Subsistence lifestyles are still prevalent in this region. People in the region have a hybrid economy which is a mix of subsistence harvests, wage jobs, and transfer payments, such as health care, supplemental nutrition assistance, social security, Alaska Permanent Fund dividends, and in some places, Native Corporation dividends. The mix of cash and wild foods, and widespread traditions of sharing are sources of resilience for people in the region. Resilience also comes from thousands of years of working together, through periods of change and uncertainty, creating a deep and holistic understanding of the ecosystem.

Indirect impacts of climate change (e.g., permafrost thaw, loss of shore-fast ice) have already directly affected communities, and will continue to do so, by eroding and damaging infrastructure and housing, contaminating water supplies, ruining traditional food storage methods, and introducing disease and pollutants. Climate change is expected to have continued indirect effects by increasing the cost of living, with global fuel price increases exacerbated by the difficulties of transporting fuel by barge. Climate change also affects animal populations and ease of access to hunt them. Subsistence hunting has become more expensive and riskier due to changes in timing of thaw and freezing. In addition, healthy animal populations may become less accessible to subsistence hunters as species' range shifts or changes in freeze/thaw make it more difficult for hunters to travel to hunt these species. Increased fire frequency in some areas, as indicated by the fire modeling for this REA, is expected to change animal habitat, unfavorably for caribou but favorably for moose.

Subsistence harvests are expected to change. Other research cited in this report show that off-shore oil development, increased shipping, and changes in sea ice may affect sea mammal populations. Loss of sea ice also limits hunter access to sea mammals. Changes in access to sea mammals will result in overall changes to subsistence harvests in communities that rely on sea mammals. Salmon harvests have already drastically dropped. The population of the Western Arctic Caribou herd (WACH) has declined in recent years and the migration through the ecoregion to winter forage on the Seward Peninsula is later in the fall. Analyses in this REA indicate potential for further change in caribou migration to the Seward Peninsula for winter forage, which could mean loss of access to the Western Arctic herd for many communities.

Without economic development, the population of the ecoregion is not likely to increase substantially; projections from this assessment indicate a potential increase from approximately 18,000 people to approximately 19,000 people by 2025. In smaller communities, out-migration is greater than natural increase. Economic change in the ecoregion could come from development of a deep water port, which is under discussion in the US Senate. Large mining prospects, located just north of the ecoregion, could also bring change. Development of mines is contingent on road or rail construction, which has, in turn become linked to the decision about a deep water port.

Key Limitations and Data Gaps

A rapid ecoregional assessment must take advantage of hundreds of existing data sets, often applying them for purposes never contemplated by their original developers. This assessment also incorporated traditional and local knowledge. These facts, and the strong need for transparency and repeatability, requires considerable documentation of sources of information and assessment methods to facilitate understanding of uncertainty and appropriate application by users of this assessment. In order to manage this uncertainty, the REA process included a series of mechanisms for documenting the data sets, information sources, processing steps, and outputs. This information is contained in the methods section of the report, the appendices, and the data product metadata.

As remote sensing, GIS, and modeling capabilities have increased along with computing capacity, scale constraints in regional analyses have generally been reduced such that relatively fine-scale mapping and analyses at sub-mile^2 or kilometer^2 resolutions are feasible. However, climate change data, which are a key component of REAs, are still relatively coarse (e.g., 4 km^2 pixels) in comparison to the resolution of other environmental data. Some products, such as the fire and permafrost projections, should be interpreted at coarser scales given the nature of the models used to produce them. Therefore, a variety of scales and resolutions are used in an REA to represent the finest practical and defensible scale of analyses and presentation depending on the source information and available modeling methods and tools. Numerous gaps in current knowledge and data were also identified and noted in the chapters as well as compiled in an overall summary of data gaps.

The fact that an REA is by definition intended to be a rapid assessment utilizing existing data rather than gathering new empirical data creates some important limitations:

- A very large number of analyses were required for this REA, conducted over a short timeframe and therefore modest resources were available for each individual analysis. The REA products are useful for the intended purposes, but they are not comparable to results of focused, multi-year studies on particular management questions.

- REA results are intended to inform landscape-scale direction that can provides context for management decisions through the step-down process.
- Only data considered relatively complete for the ecoregion could be used; therefore, although certain areas of the REA may have had more recent or more precise data, they were not used because it was not consistently available REA-wide.
- Very few source data sets and models had rigorous, quantitative accuracy assessments conducted on them; therefore it is infeasible to provide such information for REA results. Instead a qualitative ranking of confidence was assigned to provide an indication of uncertainty associated with the data sets, but further consideration of source data quality used in each analysis is encouraged.
- As conditions change and new data is developed, REAs should be updated to incorporate new information.

1 BLM's Approach to Ecoregional Direction and Adaptive Management

A note to the reader: This section was authored by the Bureau of Land Management (BLM).

Assessments help managers address problems. They provide information that can be integrated into future management action. The success of this assessment ultimately depends on how well it helps inform management decisions. Did it significantly improve understanding about the conditions of the resources being studied within the ecoregion and the consequences of particular actions? (Was it contextual?) Was that understanding integrated into manager's thinking to guide future action? (Was it integrated?) Did the assessment lead to potential solutions for the management questions? (Was it pragmatic?) (Johnson and Herring 1999).

The contract for this assessment clearly called for it to produce information designed to be integrated into specific management processes. However, the contract also clearly stopped short of including efforts to actually integrate the findings into management actions and is a toolbox and not a decision document. The BLM chose to retain responsibility for all aspects of integrating the assessment into management actions and decisions.

This section discusses a proposed process by which the BLM may integrate this assessment into management actions and decisions. This proposal is merely conceptual; no process has yet been established as a commitment or accepted as a responsibility by the BLM. The final success of this assessment depends on the BLM's efforts to integrate it into management. BLM recognizes the need and is in the process of developing a process to successfully integrate this assessment into management actions and decisions.

This proposed process helps address the environmental changes the western United States and Alaska are experiencing. To be effective, the process must address landscape/ecoregional challenges at multiple scales and across multiple jurisdictions. All BLM programs can contribute to this effort, as can all geographies. There are examples of where individual components of the BLM are developing very creative answers to these challenges. The BLM is attempting to explore innovative approaches to incorporate a process for landscape direction across programs and geographic scales. The following paragraphs briefly describe a systematic approach to these ecoregional challenges.

Managing resources at multiple scales: Traditionally, the BLM has undertaken resource management project by project, permit by permit, land use plan by plan without systematically assessing landscape scale effects. To effectively address the environmental changes the West and Alaska are experiencing, resource managers will have to develop the capacity to evaluate effects at multiple geographic scales.

Managing resources across ownerships and jurisdictions: Traditionally, resource managers have focused on activities within their own administrative units. To effectively address the environmental changes the West and Alaska are experiencing, resource managers will have to develop the institutional and technical capacity to work across ownerships and jurisdictions.

Managing resources across programs: Traditionally, resource management has been defined by programs (e.g. wildlife, range, minerals). To address the environmental changes the West and Alaska are experiencing, resource managers will have to more effectively integrate activities across programs by inter-disciplinary management.

Standardizing and integrating data: The ability to collect, synthesize, and share geospatial information about resource conditions, change agents such as wildland fire, and on-the ground management activities is a critical part of this effort. Without the ability to compile and correlate such information within and outside of BLM, it is extremely difficult to achieve conservation, restoration, and adaptation strategies and to evaluate the effectiveness of such strategies once implemented.

Systematic integration requires some fundamental shifts to the BLM's traditional business practices. The differences in this management versus traditional management are summarized below (Table 1-1). This assessment has helped the BLM to identify what processes are appropriate for the landscape approach. However, not everything the BLM does will be based on a landscape approach; a substantial amount of project work or traditional practices will still occur.

Table 1-1. Comparison of traditional BLM practices with landscape approach.

Traditional Practice	Landscape Approach
Project Focus	Landscape Focus
Program/Functional Direction	Integrated Direction Across Programs
Unit Decision-Making	Cross-Jurisdictional Decision-Making
Unit Priorities	Collaborative and Partnership Priorities
Program Accomplishments	Integrated Accomplishments Across Programs with Partnerships
Tend to authorize uses and mitigate ecological values	Ecological values and use authorizations considered equally
Ecological Component (Individual Species)	Ecological Function and Service
Agency Funding	Partnership-Leveraged Funding

Many of the landscape approach activities listed above have been part of BLM's business practice at the land use planning scale. BLM is undertaking the following activities at the landscape scale to deal with environmental changes. These activities include:

- *Rapid ecoregional assessments*
  Working with agency partners, BLM is conducting rapid ecological assessments, including this one, covering approximately 450 million acres of public and non-public lands in ten ecoregions and combinations of ecoregions in the American West and Alaska to identify potential priority areas for conservation and development. Over time, the BLM anticipates collaboration with the Department of the Interior Landscape Conservation Cooperatives in periodically updating ecoregional assessments, and identifying science needs.
- *Ecoregional direction*
  BLM is developing a standard ecoregional process, discussed in more detail below, for conserving or developing priority areas and for incorporating REA results into land use planning, environmental impact assessments, use authorizations, conservation and restoration project planning, and acquisition of conservation easements.

Ecoregional direction links REAs and the BLM's Resource Management Planning and other on-the-ground decision-making processes. Ecoregional direction helps integrate existing initiatives and program activities, and facilitates coordination across programs, offices, and with partners. Ecoregional direction establishes a regional roadmap for reviewing and updating Resource Management Plans, developing multi-year work plans for identified priority conservation and development areas, establishing Best Management Practices for authorized uses, designing regional adaptation and mitigation strategies, and developing conservation land acquisitions.

Ecoregional direction development begins with conversations among regional partners about stepping the REAs down into management. Partners that guide the step-down process will likely include BLM State Directors (or their representatives) and equivalent peers from other federal, state and Tribal agencies/entities. The partners will review the completed REA and other assessments to evaluate proposed findings and recommendations. The partners will likely:

- Delineate a schedule, process, and expected products.
- Identify proposed and ongoing activities within the region that REA informs. Such activities may include, but are not limited to, proposed or on-going assessments, planning efforts, NEPA analyses, or special area evaluations.
- Communicate with organizations potentially affected by or knowledgeable about the REA.
- Review the REA and other assessments and develop findings and recommendations.
- Conduct partnership and stakeholder outreach.

The partners will review the REA and report proposed findings and recommendations. Individual partners develop their own respective direction to implement the agreements. In the case of the BLM, this will be in the form of ecoregional direction. In developing ecoregional direction, the proposed findings and recommendations should be discussed with:

- The affected BLM's State Management Teams
- The leadership of local, state, federal and Tribal partners
- The Washington Office if there are potential national policy and coordination issues

After reviewing the proposed findings and recommendations and discussing them with the leadership of potentially affected partners, the BLM State Director(s) may issue ecoregional direction outlining what the BLM will do over the next 3-5 years to incorporate the Rapid Ecoregional Assessment into management activities. If desired, the partners may coordinate the implementation of ecoregional direction among the participating entities.

Monitoring and adaptive management

Working with partners, the BLM has a national Assessment, Inventory, and Monitoring (AIM) strategy focused on identifying core indicators of terrestrial and aquatic condition, performance indicators for fish and wildlife action plans, and scalable sampling designs to help integrate and focus BLM's monitoring activities and facilitate adaptive management.

2 Introduction

2.1 Navigating the SNK REA Report: Overview of Report Structure

A brief overview of the SNK REA report structure is provided here to aid the reader in navigation. The main report is intended to present a high-level overview of the methods, results, and interpretation of the ecoregional assessment. It consists of the following chapters:

1. Executive Summary
2. BLM's Approach to Ecoregional Direction and Adaptive Management
3. Introduction
4. Methods
5. Current Conditions
6. Future Conditions
7. Recommendations

It is accompanied by a glossary of terms and a list of acronyms; a comprehensive listing of references is included as well.

A series of appendices are provided as well. These were developed for several purposes:

1) to provide substantially greater detail on methods or data, where needed, so that interested readers could understand all the technical details of how various assessments were conducted;
2) to provide additional information on results where they could not practically fit into the main report (e.g., individual distributions were mapped or modeled for 65 CEs; a very limited subset of distribution maps is provided in the main report, and some additional maps are provided in an appendix);
3) to provide answers for management questions (MQs) that could not be addressed in the main report due to space limitations;
4) to house the conceptual models developed for the Conservation Elements (CEs); and
5) to provide documentation on the community meetings that were held early in the REA process to obtain input on management questions and other aspects of the REA process.

Because they were developed for a variety of purposes, their content varies somewhat. The following appendices are provided:

1. **Appendix A: Change Agents**: This appendix contains the detailed methods used for the assessments of climate change, permafrost, fire, and mapping current and future distributions of development footprints. (The assessment of invasive non-native species and nuisance native species was more limited in scope and therefore provided primarily in the main report. However, details on bioclimate modeling, which was also conducted for two invasive species, is contained in Appendix B.) It also contains expanded results on the overall fire modeling, and addresses some additional fire management questions that couldn't fit in the main report.
2. **Appendix B: Conservation Elements**: This appendix contains the detailed methods and results for 1) mapping or modeling the distributions of all conservation elements, 2) assessing ecological status of CEs, and 3) developing bioclimate envelope models for a subset of species CEs, as well as two invasive species.
3. **Appendix C: Places:** This appendix contains the detailed methods and results for assessing managed areas.
4. **Appendix D: Other Assessments**: This appendix contains substantial additional detail on both data and results for the socioeconomic and subsistence assessments. It also includes socioeconomic and subsistence management questions (MQs) that couldn't be included in the main report due to space limitations. It also addresses additional management questions looking at the relationship between four CAs (climate, permafrost, fire, and development) and CEs or human communities. These, too, were mostly not addressed in the main report (unless otherwise noted) due to space constraints. Both detailed methods (as relevant) and discussion are included for this content.
5. **Appendix E: Conceptual Models:** This appendix contains the descriptive text and diagrams comprising the conceptual models developed for the conservation elements. The conceptual models alone do not answer specific management questions, but formed the foundation for developing approaches to answering many management questions.
6. **Appendix F: Community Meetings Detailed Summary:** This appendix contains a detailed summary of the input provided at a series of four community meetings held in November 2010

to obtain input from communities located in the SNK ecoregion on the REA. This input helped shape the topics and management questions that were addressed in this REA.

The main report follows the structure provided by BLM for REA reports: the high-level overviews of **all** methods for **all** components of the assessment are grouped together in the Methods chapter; the results and interpretation are divided among the Current and Future Conditions chapters. The appendices generally follow that structure as well. With the large volume of material presented, when reviewing details of the results in the Current or Future Conditions chapters, the reader is reminded that it may be necessary to refer back to the main Methods chapter or to detailed methods discussions in parts of the appendices to understand how the results were developed.

2.1.1 Locating Answers to Specific Management Questions

A key navigational aid provided in the section **2.4.4 Management Questions** in this Introduction chapter is the table (Table 2-2) listing each of the Management Questions that were addressed in the SNK REA, and the specific report chapter (Current Conditions or Future Conditions) or appendix (A, B, C, or D) in which the question is addressed.

2.2 Common Terminology

Following are key terms and abbreviations used throughout this report and associated appendices; a complete listing of terms and abbreviations is found in the Glossary and List of Abbreviations sections.

- **AMT**: *Assessment Management Team*. This is the team of BLM staff and select partners in the region that developed the initial statement of work (SOW) and provided review and guidance for the contractor throughout the REA.
- **CA**: *Change Agent*. These are the features or processes that can negatively impact Conservation Elements (and in some cases can have neutral or beneficial effects on certain CEs). Development, invasive species, wildfire, and climate change effects are the four primary change agents addressed in this REA.
- **CE**: *Conservation Element*. These are the natural resource features assessed in the REA and include ecological systems, species, and hydrologic features.
- **KEA**: *Key Ecological Attribute*. Specific attributes of the size, condition, or landscape context of an ecological system; KEAs inform the identification of measurable indicators for assessing the ecological status of CEs.
- **MQ**: *Management Question*. These are questions important for guiding natural resource management and land use decisions developed by the AMT. The REA provides information and analysis results to address the management questions.
- **REA**: *Rapid Ecoregional Assessment*
- **REAWP**: *REA Work Plan*
- **SNK**: *Seward Peninsula – Nulato Hills – Kotzebue Lowlands*
- **SOW**: *Statement of Work* described in the original request for proposals.

2.3 REA Elements

REAs are grounded in ***management questions (MQs)*** that specify the key information needs of managers as expressed by the Assessment Management Team (AMT). REAs describe and map ***conservation elements (CEs)***, which are generally features of high ecological value or sensitivity. REAs look across all lands in an ecoregion to identify regionally important habitats for fish, wildlife, species of concern, and other features of management interest such as permafrost. REAs then gauge the potential of these CEs to be affected by four overarching environmental ***change agents (CAs):*** climate change, wildfires, invasive species, and development (such as land use, energy development, infrastructure, or hydrologic alterations). REAs also map and describe ***places,*** including watersheds, lands under different ownership jurisdiction or management, and areas that have been previously identified for conserving important ecological or cultural resources. REAs are designed to be ***scenario-based assessments***: they characterize CEs and CAs at multiple points in time based on current and projected conditions, to the extent permitted by available data and modeling tools. For management and planning purposes, BLM identified three time frames in which CEs and CAs would be characterized: current time period (2010), near future time period (2025), and a mid-century time period (2060).

In summary, REAs do the following:

- Identify and answer important management questions relating to CEs, CAs, and related features of interest
- Document key resource values, which are referred to as conservation elements, with a focus on regionally significant terrestrial habitats, aquatic habitats, and species of concern
- Describe influences of four environmental change agents: climate change, wildfire, invasive species, and development
- Describe places where management decisions occur or where resource values have been identified
- Assess the effects of current and forecasted trends
- Identify and map key opportunities for resource conservation, restoration, and development
- Identify science gaps and data needs
- Provide a baseline to evaluate and guide future management actions

REAs do not prioritize or allocate resource uses or make management decisions. They provide science-based information and tools for land managers and stakeholders to consider in subsequent resource planning and decision-making processes.

2.4 How REAs Are Prepared

2.4.1 Teams and Partnering

2.4.1.1 Assessment Management Team

An Assessment Management Team (AMT) composed of BLM managers, partner agencies, and technical specialists from within the ecoregion was assembled by BLM to oversee the REA. At the beginning of the REA process, other federal and state agencies, native corporations and tribes were invited as partners to the Assessment Management Team, including representatives of relevant Landscape Conservation Cooperatives. USGS was retained as a peer reviewer of REA products. Staff of the BLM's National Operations Center (NOC) were engaged as members of the project management team, and the lead BLM project manager (PM) was located in the BLM Alaska State Office. The BLM PM coordinated communications, and working in conjunction with the contracting officer, provided technical standards and oversight to the contractors. The AMT guided the assessment and in conjunction with the BLM PM, oversaw the work of the contractors who performed the technical data management and analysis tasks required by the REA.

2.4.1.2 Contractor Team and Collaboration

This REA was conducted as a collaboration between the AMT (see Acknowledgements for listing) and the contractor for this REA: the NatureServe team. The NatureServe team included the following partner organizations and individuals:

- NatureServe
- Alaska Natural Heritage Program (AKNHP; University of Alaska, Anchorage)
- Scenarios Network for Alaska and Arctic Planning (SNAP; University of Alaska, Fairbanks)
- Institute of Social and Economic Research (ISER; University of Alaska, Anchorage)
- Dr. Healy Hamilton
- California Academy of Sciences
- Sound Science LLC
- Margaret J. King and Associates

Team members were generally organized thematically around CEs (terrestrial and aquatic subteams) and CAs (development, fire, invasives, climate subteams), although many staff played overlapping roles. The AMT and affiliated participants (see Acknowledgements) were loosely organized into similar thematic subteams to advise the NatureServe team in particular areas such as fire, invasives, hydrology, etc. They interacted primarily via face-to-face workshops and topical webinars. These subteams also provided review of draft products.

2.4.2 Defining the Ecoregion

BLM selected the composite area of the three ecoregions, Seward Peninsula, Nulato Hills, and Kotzebue Sound Lowlands, as defined by Nowacki et al. (2001) as the basis for the REA boundary. To support edge-matching across REAs and to capture CA effects at REA boundaries, contractors were required to expand the REA boundary by including all 5th level Hydrologic Units (HUCs) that intersect the ecoregion boundary. The total area of the Rapid Ecoregional Assessment project boundary is approximately 60,000 miles^2. The resulting SNK ecoregion is shown in Figure 2-1.

Figure 2-1. Project boundary (in red) for the Seward Peninsula – Nulato Hills – Kotzebue Lowlands ecoregion, with ecological subdivisions.

2.4.3 REA Phases and Workflow

REAs are prepared in two phases. The first phase is the ***pre-assessment***, which refines management questions posed by the Assessment Management Team (AMT), solidifies the lists of CEs and CAs, and identifies the data and methods available for analysis. The second phase is the ***assessment,*** in which the analysis is conducted and the assessment report, maps, and supporting documents are prepared. The phases of the REA are organized into seven tasks (Figure 2-2 and Table 2-1); the SNK REA was conducted according to these phases and tasks.

Figure 2-2. REA workflow divided into pre-assessment and assessment phases with regular workshops. The content of each of the first three workshops is listed beneath each workshop symbol in white text. Workshop 4 marked the preparation of the work plan with formal timelines, workflow, and review process. Workshops 5 and 6 provided forums for presenting analyses and products described in the final report.

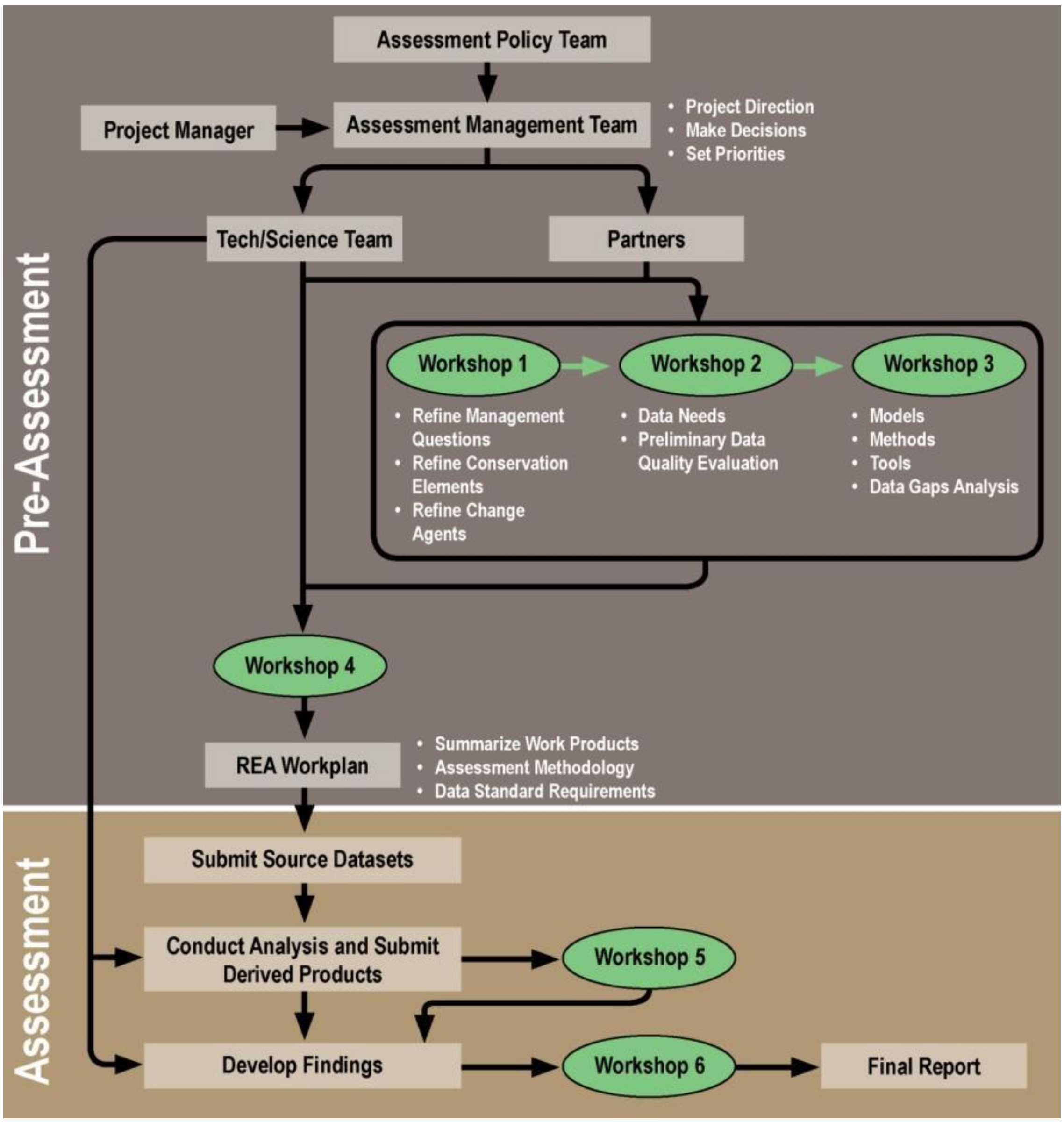


Table 2-1. BLM REA phases and tasks.

Phase #	Phase	Task #	Revised Task #	Task Description
Phase I	Pre-Assessment	Task 1	NA	Refine Management Questions, Select Conservation Elements
Phase I	Pre-Assessment	Task 2	NA	Identify, Evaluate, and Recommend Potential Data
Phase I	Pre-Assessment	Task 3	NA	Identify, Evaluate, and Recommend Models, Methods, Tools
Phase I	Pre-Assessment	Task 4	NA	Prepare Rapid Ecoregional Assessment Work Plan (REAWP)
Phase II	Conduct Assessment	Task 1	Task 5	Compile and Generate Source Datasets
Phase II	Conduct Assessment	Task 2	Task 6	Conduct Analyses and Generate Findings
Phase II	Conduct Assessment	Task 3	Task 7	Prepare Rapid Ecoregional Assessment Report and Documents

2.4.4 Management Questions

The AMT held meetings prior to Phase I (the pre-assessment phase) to identify Management Questions (MQs) of interest for assessment. A number of MQs were provided in the Statement of Work (SOW) to be treated as candidate MQs that would be evaluated for feasibility of assessment through Tasks 1-4. In addition, four community meetings were held to provide information about the REA process and get input from various organizational representatives that potentially will use the data and information resulting from the REA. (Summaries of the community meetings are compiled in Appendix F.)

BLM provided an initial set of 81 MQs. Input from the community meetings produced another 58 questions of interest, and an additional 28 questions were suggested by the contractor team. There were a number of MQs dealing with socio-economic and subsistence issues. Most MQs fall into the following generalized categories:

- Where is it? (e.g., CEs, CAs, Places)
- Where does it coincide with other features? (e.g., CEs with CAs)
- Where and how might the CEs be affected by CAs, either now or in the foreseeable future?

The questions were evaluated by the contractor over the course of the REA based on the following considerations:

- **Data availability**: do data exist to answer the MQ?
- **Model availability**: do suitable methods exist or could feasibly be created to answer the MQ?
- **Clarity**: did the MQ need to be rephrased to provide an unambiguous answer or to fit the availability of data or modeling methods to answer it?

Recommendations by the contractor for modifying or deferring the MQs (and in some cases adding or splitting MQs) were presented to the AMT at AMT workshops and/or in memoranda and were accepted, modified, or rejected. Additions, deferments, and changes to MQs from the original list provided in the SOW were tracked in the detailed master MQ table. The result was the assessment of 57 final MQs listed in Table 2-2. Because of the large number of MQs assessed in this REA, not all MQ results could practically be addressed within set page limits of this report; however, full results for all MQs are provided in the appendices.

Table 2-2. Final list of Management Questions for the SNK REA and the REA report chapter or appendix where they are addressed. The columns at right indicate in which chapter (Current Conditions or Future Conditions) and which appendix (A, B, C, or D) each question is addressed. Not all MQs could practically be addressed in the main report, but every single MQ is addressed within one of the appendices.

MQ #	Group	Management Question	Report Chapter	Appendix
86	Native Plant Communities	What habitats support terrestrial species of concern (rare plants, rare animals, and subsistence species)?		B
87	Native Plant Communities	How will habitats that support terrestrial species of concern likely change due to fire over the next 15 and 50 years?	Future	A
88	Native Plant Communities	What are the proportions of CEs that coincide with different management areas?	Current	C
113	Aquatic Resources	Where are the important aquatic resources, such as spawning grounds and other fish habitats? (herring spawning grounds and areas used by waterfowl?)	Current	B
114	Aquatic Resources	What is the condition of these various aquatic systems?	Current	B
116	Aquatic Resources	Where are predicted changes in hydrologic regime associated with important aquatic resources?		D
117	Aquatic Resources	Where are predicted changes in air temperature associated with important aquatic resources?		D
60	Species	What is the current distribution of each CE?	Current	B
62	Species	Where do current CE distributions overlap with CAs?	Current, Future	D
64	Species	Where are CEs whose habitats are **systematically** threatened by CAs (other than climate change)?	Current, Future	D
68	Species	What CE populations and movement corridors overlap with CAs?	Current, Future	D
79	Species	Given current and anticipated future locations of change agents, not including climate change, where will potential habitat enhancement/restoration locations likely occur?		D
178	Species	For game units that overlap REA, what are the current populations and trends in population for musk-ox, caribou, and moose?		D
147	Climate	What are the potential future climate scenarios for temperature and precipitation?	Future	A
63	Climate	Where will the distribution of CEs and wildlife ranges likely experience significant change in climate?	Future	B

MQ #	Group	Management Question	Report Chapter	Appendix
156	Climate, Permafrost	What are the current soil thermal regime dynamics and how are these predicted to change in the future?	Current, Future	A
157	Climate, Permafrost	Where are predicted changes in soil thermal regimes associated with aquatic communities?		D
159	Climate, Permafrost	Where are predicted changes in soil thermal regimes associated with communities/villages?		D
29	Permafrost (& CEs)	Where are predicted changes in river erosion associated with relevant CEs?		D
129	Fire	What is the fire history of the region and what is the potential future fire regime? What are the implications for vegetation?	Current, Future	A
129.5	Fire	What does the paleorecord reveal about fire history?		A
126	Fire	What is the known lightning strike frequency? Do these data show a significant trend over time?		A
120	Fire (& Permafrost)	How is the potential future fire regime anticipated to impact permafrost?		D
122	Fire (& CEs)	Where are predicted changes in future fire regime associated with rivers?		D
130	Fire (& CEs)	Where are areas of predicted high future fire risk associated with current caribou habitat, winter range?		D
132	Fire (& Communities)	What is the probability of fire, based on model scenarios, near existing communities?		D
45	Development	Where are current and planned oil/gas activities located and where do they overlap with CEs or other relevant habitats?	Current, Future	A, D
46	Development	Where are historic, current, and potential mining activities located, and where do they overlap with CEs or other relevant habitat?	Current, Future	A, D
49	Development	Where are historic, current, and potential recreation use areas located, and where do they overlap with CEs or other relevant habitat?	Current, Future	A, D
50	Development	Where are current and planned roads located and where do they overlap with CEs and other relevant habitat?	Current, Future	A, D
51	Development	Where are historic, current, and military sites areas located, and where do they overlap with CEs or other relevant habitat?	Current, Future	A, D
52	Development	Where are potential wind and biomass sites located within 25 miles of communities?	Current, Future	A, D
111	Development	Where are hazardous waste sites?	Current, Future	A, D

MQ #	Group	Management Question	Report Chapter	Appendix
33	Development, Climate	Will the changes to permafrost and hydrological resources affect mining practices or opportunities (i.e., the NPDES permits for waste water)?		D
134	Invasive Species	Where have recent beetle outbreaks occurred?	Current	
138	Invasive Species	What is the current distribution of invasive species included as CAs?	Current	
139	Invasive Species	Given current patterns of occurrence, what is the potential future distribution of invasive species included as CAs? [From narrow list of species that are CAs.]	Future	B
143	Invasive Species	What are the known and likely introduction vectors of invasive species?	Current	
15	Socioeconomic	Where is hunting and tourism taking place and how frequently?		D
16	Socioeconomic	(A) What is the current socio-economic profile for each community? (B) How are they likely to change under development and climate scenarios?	Current, Future	D
18	Socioeconomic	How are changes in climate likely to affect tourism destination sites, numbers of tourists and revenues?		D
28	Socioeconomic	What types of traditional and local knowledge data exist for the region and then how can these data be best incorporated into management decisions?	Current	
30	Socioeconomic	Where will losses of lakes potentially affect water supply to villages?		D
102	Livestock (Reindeer Grazing)	Where are the current populations of Reindeer? What is the current and historic herd size?		D
103	Livestock (Reindeer Grazing)	Will suitable habitat for caribou be available with climate change?	Future	B, D
104	Livestock (Reindeer Grazing)	Where will current Reindeer grazing areas experience climate completely outside their normal range?		D
105	Livestock (Reindeer Grazing)	Where will current populations of reindeer experience overlap with Change Agents?	Current, Future	D
106	Livestock (Reindeer Grazing)	How have the reindeer herds changed over time? How do herds affect grazing areas?		D
2	Subsistence	How could changes in sea mammal harvests potentially affect land based hunting and fishing?	Future	D
3	Subsistence	What is the current population and range of moose?		D
4	Subsistence	How much have harvests (lbs.) changed over the past 20 years?	Current, Future	D
6	Subsistence	Which species make up the largest share (lbs.) of subsistence harvests? How is this changing?	Current, Future	D

MQ #	Group	Management Question	Report Chapter	Appendix
7	Subsistence	Given current and estimates of future subsistence species populations, are harvest regulations adequate to protect subsistence species populations?	Future	D
9	Subsistence	How have hunting and fishing regulations affected general hunting and fishing harvests?		D
10	Subsistence	What are the current ranges of subsistence species? Where are the subsistence communities?	Current	B, D
11	Subsistence	In which locations are climate change events likely to affect subsistence species?	Future	B, D
44	Development, Subsistence	How are transporters/tourism/sport hunt and fishing affecting the migration patterns of caribou?	Future	D

2.5 Modeling

2.5.1 Conceptual Modeling

Science-based assessments such as REAs must compile and synthesize large amounts of existing knowledge and data for the area being assessed. Conceptual models provide a practical mechanism for summarizing current knowledge, documenting assumptions, and illustrating how those assumptions and data have been integrated to produce assessment results. Conceptual models are commonly provided as descriptive text or “box-and-arrow” diagrams. An overarching conceptual model was developed to broadly synthesize current understanding about the ecoregion as a whole. The conceptual model for the ecoregion lays out an overall framework for understanding pattern and process throughout the ecoregion, and provides an ecologically based framework for organizing the assessment. Numerous specific conceptual models were then developed to describe the current understanding of each CE and its likely interactions with CAs (see Appendix B regarding CE conceptual model methods and Appendix E for the compilation of CE conceptual models).

2.5.2 Spatial Modeling

Conceptual models can often be translated into spatial models that can be used to investigate and answer management questions by analyzing or combining mapped information. Spatial models can be illustrated conceptually using process diagrams showing how spatial data inputs will be combined and processed. The actual processing of the spatial data results in the spatial model output, which can be displayed as a map. For the REA, these spatial models aim to directly address the assessment needs of the MQs. Spatial modeling included the following:

- Generating distribution maps of current and/or potential future distribution of CEs, CAs and Places from existing data
- Analyzing the spatial coincidence of CAs, CEs, and managed areas
- Evaluating the effects of CAs on CEs (e.g., on the forecasted extent or potential ecological status of CEs)
- Conducting specific advanced analyses to answer MQs such as identifying potential areas for restoration

2.5.2.1 Key REA Products

The following list is not exhaustive but describes the general categories of products resulting from the REA:

- Conceptual and spatial process models
- Metadata for all geospatial products
- Geospatial maps of the distribution of CEs
- Geospatial maps of ecological integrity by 4 km^2 (2x2 km) grid cell or 5th level watershed
- Geospatial maps of the distribution of CAs
- Geospatial results of assessments, including ecological status of CEs
- Tabular results of assessments
- Final report
- Appendices to final report, including results for MQs

2.6 Ecoregion Model

For Rapid Ecoregional Assessments (REAs), conceptual ecological models assist with organizing current knowledge and communicating key assumptions about the environmental controls and dynamics that characterize the regional landscape. Conceptual models commonly include "box-and-arrow" diagrams, tabular summaries, and textual descriptions. The assessment team followed current recommended approaches (e.g., Gross 2003) to organize a conceptual model for the ecoregion. A wealth of existing descriptive information, including conceptual models developed for the National Park Service Inventory and Monitoring programs (Lawler et al. 2009) and ecoregion descriptions from other federal agencies (Nowacki et al. 2001, NRCS 2006, McNab et al. 2007) was available to define the SNK ecoregional conceptual model.

2.6.1 Assessment Boundary

To define the ***spatial bounds*** of the model, the assessment team utilized the boundary provided by the BLM in the statement of work: the composite area of the three ecoregions, Seward Peninsula, Nulato Hills, and Kotzebue Sound Lowlands, as defined by Nowacki et al. (2001) and all 5th level, 10-digit hydrologic units that overlap the ecoregion boundaries (Figure 2-1). The total area of the Rapid Ecoregional Assessment project boundary is approximately 60,000 miles^2.

The ecoregion falls within Provinces M-131 Open woodland – tundra, M-123 Tundra – meadow, and 123 – Tundras, as defined by Bailey (2008). It falls into the Arctic EcoDivision as defined by NatureServe (Comer et al. 2003). It includes the northern extreme of the Western Alaska Land Resource Region (NRCS 2006) and southern extreme of the Northern Alaska region; both being Arctic in nature, extending from the Alaska Peninsula to the south up across the Alaska North Slope. The Nulato Hills subregion of this REA ecoregion falls within Western Alaska, and is defined by MRLA 240 and 230. The Seward Peninsula subregion includes portions of MRLA 240 and all of MRLA 241. The Kotzebue Lowlands subregion includes MRLA 242.

These ecoregions comprising the REA ecoregion are surrounded by five other ecoregions. Due to the inclusion of the HUC units, portions of the following ecoregions occur within the REA project boundary: 1) the Brooks Foothills ecoregion to the north (28 miles^2), 2) the Kobuk Ridges and Valleys ecoregion to the north and east (3,798 miles^2), 3) the Kuskokwim Mountains ecoregion with two small sections in the east and southeast (79 miles^2), 4) the Yukon River Lowlands ecoregion to the east (4,856 miles^2), and 5) Yukon-Kuskokwim Delta ecoregion to the south (3,246 miles^2). The Chukchi Sea, Bering Straits, and the Bering Sea abut the western boundary of the REA project area. The intent of the hydrologic unit buffer is primarily to include change agent processes falling outside of the ecoregion but affecting CEs within the ecoregion. Thus, CEs peripheral to the core SNK ecoregion but falling within the buffer are not assessed in this study.

Overview of Physiography: The western extent of the Brooks Range lies to the north of the Kotzebue Sound Lowlands ecoregion, with the Yukon River bordering the eastern edge of the Nulato Hills Ecoregion, and the Yukon River Delta bordering the southern edges of the Nulato Hills Ecoregion (Figure 2-3 and see also Figure 2-1). The Seward Peninsula - Nulato Hills - Kotzebue Sound Lowlands ecoregions can be distinguished from the adjacent ecoregions by the low elevations and predominately flat Kotzebue Sound Lowlands draining the Noatak and Kobuk River deltas. Lakes and ponds are abundant throughout the Kotzebue Sound Lowlands, with wet tundra dominating the poorly drained soils. The Seward Peninsula is unique with mainly tundra in the broad valleys and convex hills with scattered, high-elevation mountains. The Nulato Hills ecoregion drains the region from a northeast to southwest direction by a series of hills. The Nulato Hills ecoregion supports tundra at higher elevations and transitions to sub-Arctic species in the lower elevations.

Figure 2-3. Physiography of the Seward Peninsula-Nulato Hills-Kotzebue Lowlands REA project area.

2.6.2 Conceptual Ecoregion Model

The purpose of this model is to articulate key assumptions about regional landscape pattern and process that informed the selection and analysis of CEs and CAs. This overarching description and model provided the framework for a series of component models for the ecoregion. The ***temporal bounds*** of this conceptual model are intended to encompass characteristics of the past two centuries, but center on the 20th century and decade of 2001-2011. This time period reflects the climatic regimes, ecological patterns and processes, and CAs that are most applicable to this assessment. This assessment addressed future time periods in the evaluation of land use scenarios and climate-induced stress, including climate-induced alterations to fire regime and permafrost distribution, but for conceptual modeling, the initial set of assumptions lead up to today.

2.6.2.1 Biophysical Controls

Regional Climate Regime*:* Climate is a major driver in determining ecosystem distributions in Alaska (Jorgenson et al. 2004). Narrative descriptions of Alaska ecoregions define the Kotzebue Sound Lowlands, Seward Peninsula, and Nulato Hills as moist polar ecoregions (Nowacki et al. 2001). Temperatures at all weather stations in northwest Alaska have similar seasonal patterns with short, cool, wet summers and long, cold winters, with most precipitation generally falling between July and September. Strong precipitation and temperature gradients are evident, with colder mean annual air temperatures in the north and higher precipitation in the west. The coastal areas generally experience a more maritime climate with cool foggy summers and more moderate winter temperatures, grading into a more continental climate further into the interior. In the winter, however, the Bering and Chukchi Seas freeze over entirely, creating a pathway for cold Siberian air in the coastal areas. High winds are also common along the coastal areas and increase with winter storms. Temperatures also vary along an elevation gradient with higher elevations having cooler summers and generally warmer and windier winters. Large mountains (described in the section below on regional physiography) on the Seward Peninsula act as a barrier limiting moisture from the Bering Sea, with precipitation rates twice as high south of the mountains (Jorgensen et al. 2004). Mean maximum/minimum annual temperatures range from 28.1/15.7°F at Kotzebue (1949-2010), 33.4/19.6°F at Nome (1949-1999), to 33.3/19.1°F at Unalakleet with interior temperatures of 32.2/16.7°F at Galena (1949-1993) and 37.5/21.8°F at St. Mary's (1967-2000) (WRCC 2010), although seasonal temperatures of course vary greatly. Total annual precipitation/snowfall ranges from 9.7/52.9 inches in Kotzebue, 16.0/62.2 inches in Nome, 13.0/35.3 inches in Unalakleet, 31.2/63.4 inches in Galena, and 19.1/67.8 inches in St. Mary's (WRCC 2010). Snowfall accuracy in these regions may be compromised by blowing snow and must be considered when assessing precipitation records. Surface waters generally freeze over from early to mid-October with breakup in mid- to late May (Lawler et al. 2009).

Regional Physiography: The Kotzebue Sound Lowlands (Figure 2-1) consists of coastal plains draining several large river systems surrounding Kotzebue Sound on the Chukchi Sea. This ecoregion is flat and low-lying (<330 ft) and areas with little to no topographic relief tend to be poorly drained, although areas with terraces, hills, and sand dunes are well drained. The Kotzebue Sounds Lowlands has a high density of lakes, estuaries, and freshwater and contains one of the highest lake areas and densities in Alaska (Arp and Jones 2008). Lakes and ponds comprise up to 15 to 20 percent of the ecoregion and wetlands occupy 76 percent of the area (McNab and Avers 1994). The Kotzebue Sound Lowlands consist primarily of depositional features by morainal, stream, or lake deposits from material washed or blown from nearby hills and outwash plains (Karlstrom et al. 1964). Ice-related features dominate the landscape, including pingos and thaw lakes. Moraines from pre-Wisconsin glacial advances are common. The geology is predominantly marine sedimentary rock from the Cenozoic and Cretaceous (Beikman 1980). At higher elevations, igneous bedrock under volcanic soils may relate to lake development (Arp and Jones 2008). Soils tend to be wet and shallow and are almost always saturated in the summer due to thick permafrost in areas with significant loess deposits (Brown et al. 1997, Jorgenson et al. 2004). The soils consist mainly of Histic Pergelic Cryaquepts and Pergelic Cryofibrists and are formed by silt or sand alluvial deposits, volcanic ash, or loess (NRCS 1979). With standing water common in the tundra, sedge mat communities dominate. In better drained areas such as peat ridges, drainage ways, and polygonal features, woody species like white spruce, willows, alder, and paper birch occur. Grasses dominate the coastal dunes. Black spruce forests are also abundant along the Kobuk River. The floodplains receive frequent inundation through seasonal flooding.

The Seward Peninsula Ecoregion (Figure 2-1) is a mosaic of coastal plains, extensive convex hills with scattered broad valleys, and a few isolated groups of rugged mountains. Streams and small scattered lakes occupy the larger valleys. On hill slopes and ridges, soils are gravelly over weathered bedrock and in the lower elevations they tend to be formed by colluvial and alluvial sediments (Karlstrom et al. 1964). Soils include Histic Pergelic Cryaquepts, Pergelic Cryaquepts, Typic Cryochrepts, Lithic Cryorthents, and Pergelic Cryumbrepts (NRCS 1979). They are predominately poorly drained, shallow, and organic over permafrost. The permafrost is continuous; however, it ranges from thin to moderately thick. Permafrost features such as pingos and patterned ground are present throughout the region. The geology is complex with metamorphosed mica and calcareous schists, marbles, gneissic, and other metavolcanic rocks of the Paleozoic age (Beikman 1980). Volcanism is evident with lava flows, cinder cones, hot springs, and several large maar lakes formed by eruptions through deep permafrost (Béget et al. 1996). During the Pleistocene only the tallest mountains were glaciated with the highest peak in the region reaching 4,600 feet (Matthews 1974, Hopkins et al. 1983, Kaufman and Hopkins 1986, Kaufman et al. 1991). Remnant glacial features such as cirque lakes are found at the highest elevations. Since the Seward Peninsula was relatively ice-free, it served as a migration corridor between North America and Asia; thus strong ecological similarities between the regions exist today. Tundra plant diversity is high in this ecoregion due to its past connection to Asia, occurring in a transition zone between the Arctic and sub-Arctic, and the presence of both acidic volcanic rock and limestone. Tundra vegetation dominates with alpine *Dryas*-lichen tundra and barrens at higher elevations and wet sedge-tussock tundra at lower elevations. In areas with better drainage, low-growing ericaceous and willow-birch shrubs persist and in river valleys willow, birch, and spruce-hardwood forest occur.

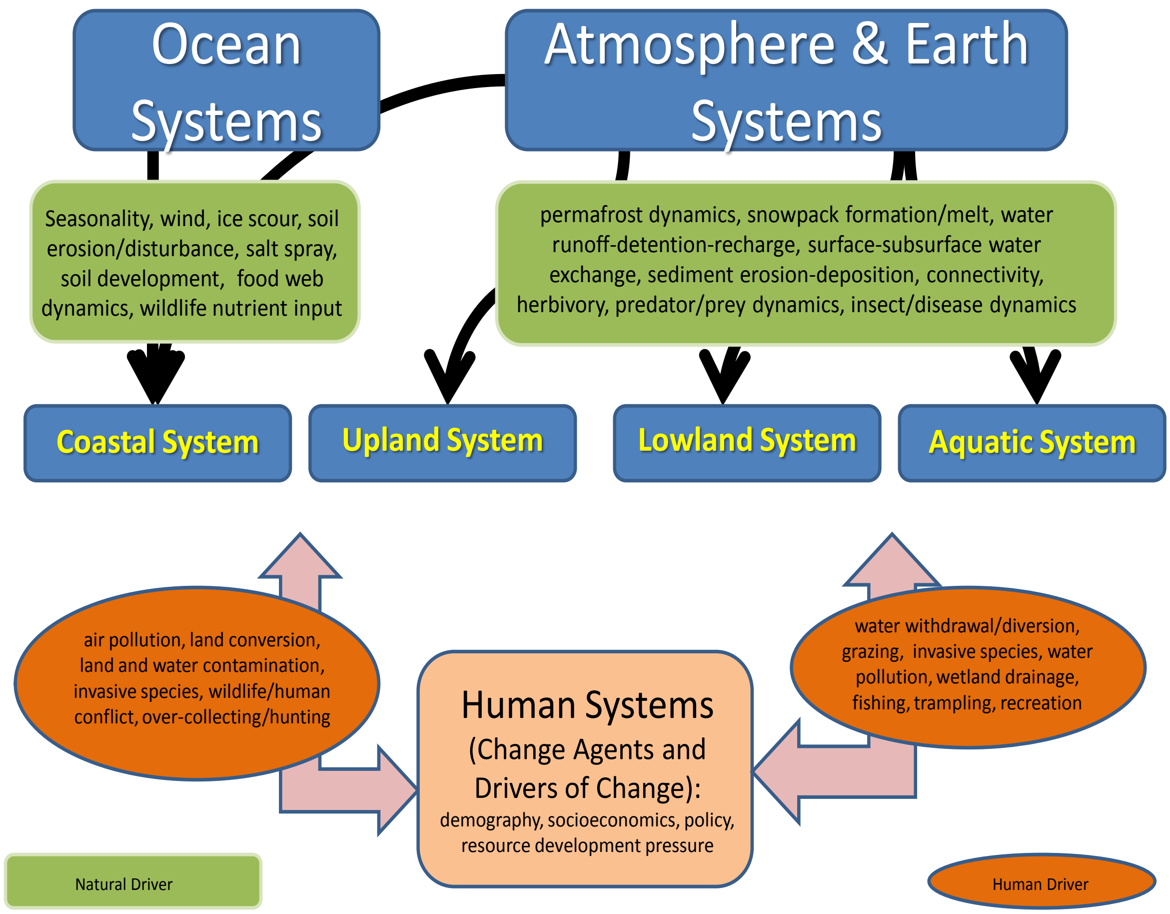
The Nulato Hills Ecoregion (Figure 2-1) consists of a series of low-lying hills trending in a northeast-southwest direction with rivers occupying the narrow and flat-bottomed valleys, draining into Norton Sound. These hills have even-crested ridges, rounded summits, and gentle slopes and are the remnants of an ancient mountain range that experienced extended periods of down-cutting, weathering, and erosion. The bedrock is mainly Upper Cretaceous and the soils are predominately Aquepts (NRCS 1979, Beikman 1980). In areas with poor drainage due to permafrost, Cryaquepts soils dominate and in well-drained high ridges, Cryumbrepts and Cryorthents are the main soils (NRCS 1979). Due to the relatively low elevation of the Nulato Hills (elevations between 1,000-2,000 ft with a maximum elevation 4,040 ft), this ecoregion was also predominately ice-free during the Pleistocene and served as part of the Beringia migration corridor between Asia and North America. Permafrost is continuous in the entire region, but ranges from thin to moderately thick. Ice-formed features such as pingos and patterned ground occur. The vegetation tends to follow an elevational gradient with *Dryas*-lichen and sedge-ericaceous shrub tundra on the hilltops, shorter to taller willow-birch-alder shrublands gradating at lower elevations, and spruce and birch woodlands at the lowest elevations.

2.6.2.2 Major Systems for Conceptual Modeling

Existing model concepts developed by Lawler et al. (2009) were adapted, recognizing major patterns in climatic, oceanic influence, and physiography. Pervasive influences of Arctic climate regimes interact with the montane, lowland, and coastal physiography to provide overarching biophysical controls on nested ecosystems (Figure 2-4). Affected in part by variation in solar radiation and air density, seasonal temperature and precipitation regimes vary along both latitudinal and elevational gradients. Combined, these controlling regimes set up regional patterns in coastal dynamics, wind, and dry/wet atmospheric deposition.

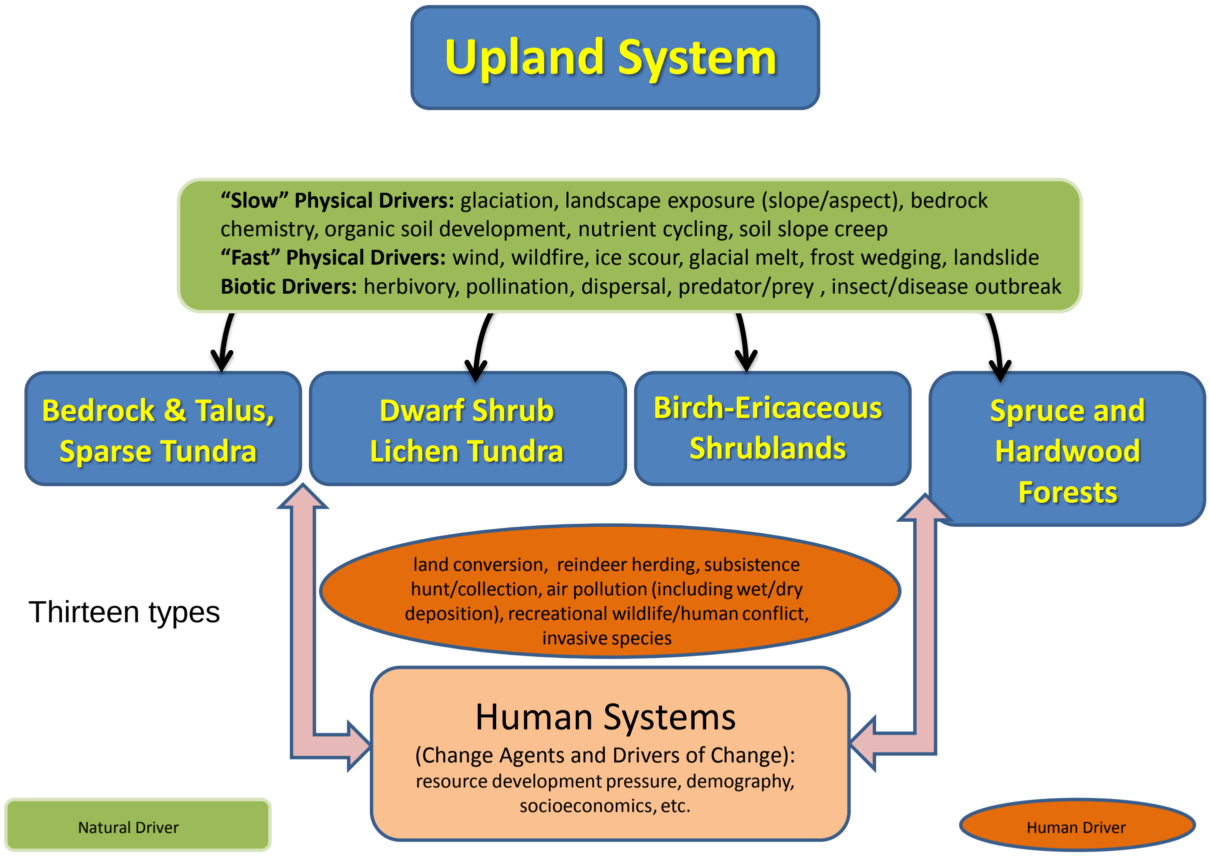
The human dimension enters as a distinct model component with socioeconomic and demographic drivers of change in land and water use and policy overlay other model components. The human dimension is addressed in several MQs as both a human benefit and as a current or potential CA. Natural drivers such as herbivory and freeze-thaw dynamics are affected by locally intensified grazing, water diversions and gravel mining. Predator/prey dynamics may be influenced by patterns in hunting and collecting. Introduction of invasive plant species closely follows human land use patterns for settlements, energy development (e.g., mining, oil/gas), or transportation infrastructure.

Figure 2-4. Conceptual model for the Seward Peninsula-Nulato Hills-Kotzebue Lowlands ecoregion



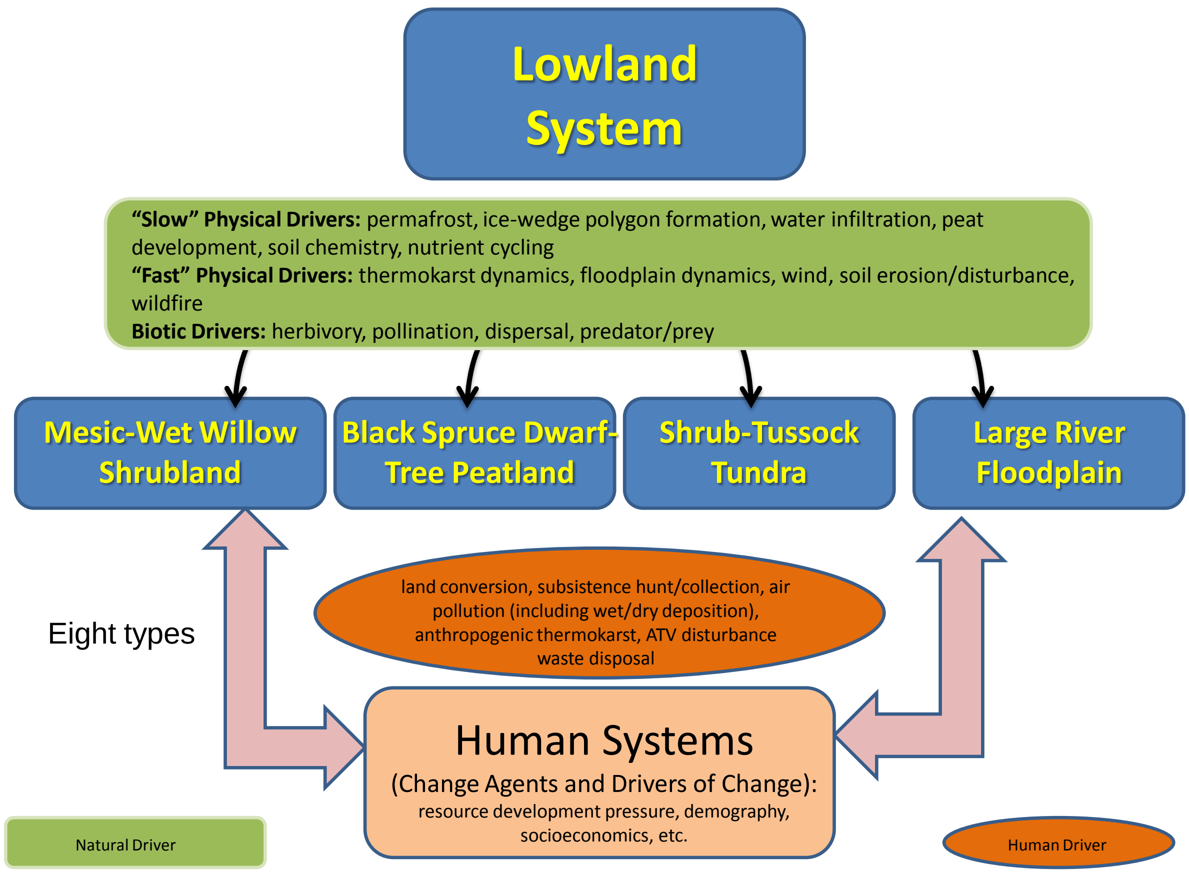
Four major model components were defined, acknowledging the interacting roles of temperature, water, and coastal dynamics in this Arctic ecoregion. Upland systems were first distinguished as those driven generally by extreme temperature exposure and extreme drainage (Figure 2-5). At this level, natural drivers are treated as "slow" physical drivers – those dynamics that often encompass decades to centuries for significant measurable change (e.g., glaciation, bedrock exposure and chemistry, permafrost and organic soil development, nutrient cycling, landscape exposure, or solifluction), or as “fast” physical drivers such as wind, wildfire, ice scour, glacial melt, frost wedging, or landslide. These are further distinguished from biotic drivers, such as herbivory, pollination, dispersal, predator/prey dynamics, or insect/disease cycles. These natural drivers vary across major ecosystem types resulting in sparsely vegetated bedrock, cliff, and talus or sparse tundra communities, dwarf shrub lichen tundra, taller shrublands, including predominantly birch and ericaceous shrublands, and woodlands dominated by spruces and hardwoods. Thirteen major upland ecosystem types were identified (see Table 2-3 under the Coarse-Filter Elements section).

Figure 2-5. Upland model components for the Seward Peninsula-Nulato Hills-Kotzebue Lowlands ecoregion.



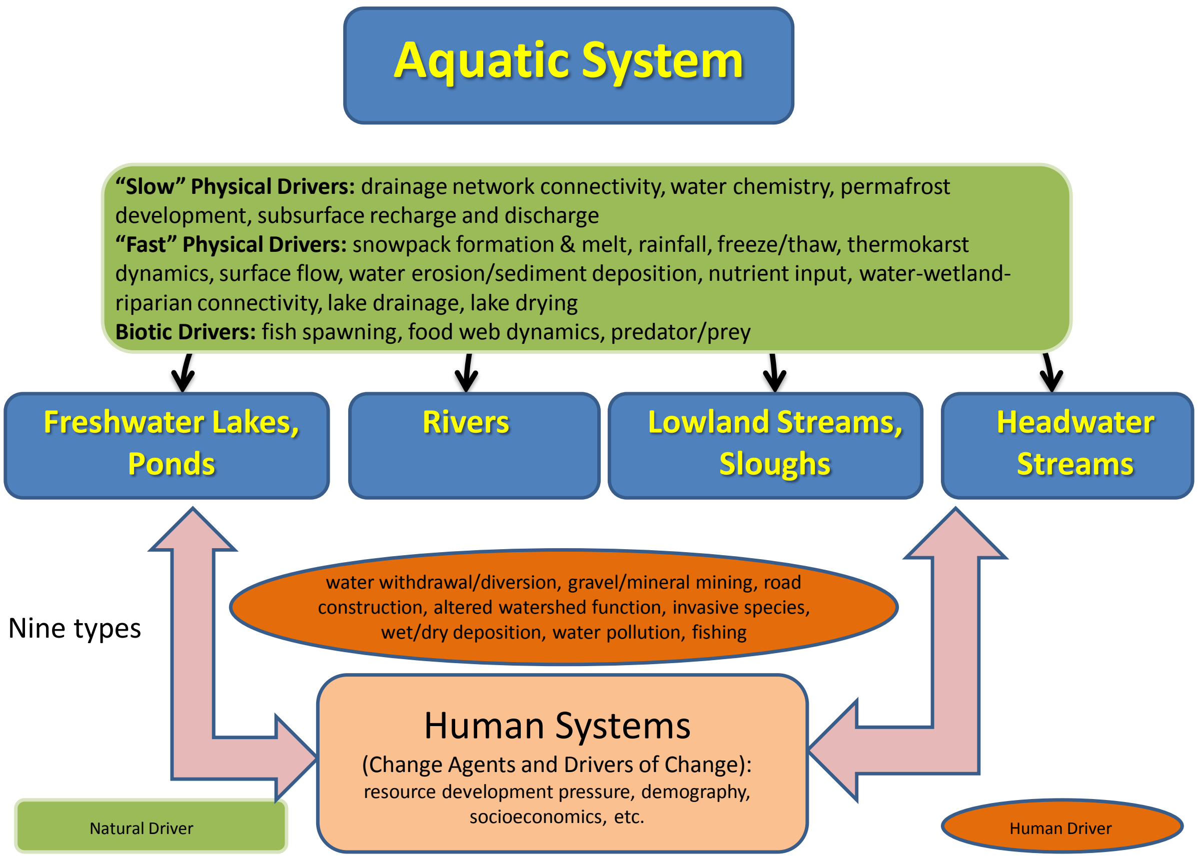
Lowland systems encompass the gradient from relatively moderately drained, “moist” uplands, typically where alluvial soils are deeper and permafrost is predominant (if not continuous) (Figure 2-6). Here the “slow” physical drivers include ice-wedge polygon formation, water infiltration, and peat development. “Fast” physical drivers include river floodplain dynamics, thermokarst dynamics, wind, soil erosion, disturbance, and wildfire. Biotic drivers here include herbivory, dispersal, predator/prey dynamics, and insect/disease dynamics. Eight major ecosystem types within this lowland category were identified, including Arctic mesic-wet willow shrubland, boreal black spruce-dwarf tree peatland, Arctic shrub-tussock tundra, and large river floodplains (see Table 2-3 under the Coarse-Filter Elements section).

Figure 2-6. Lowland model components for the Seward Peninsula-Nulato Hills-Kotzebue Lowlands ecoregion.



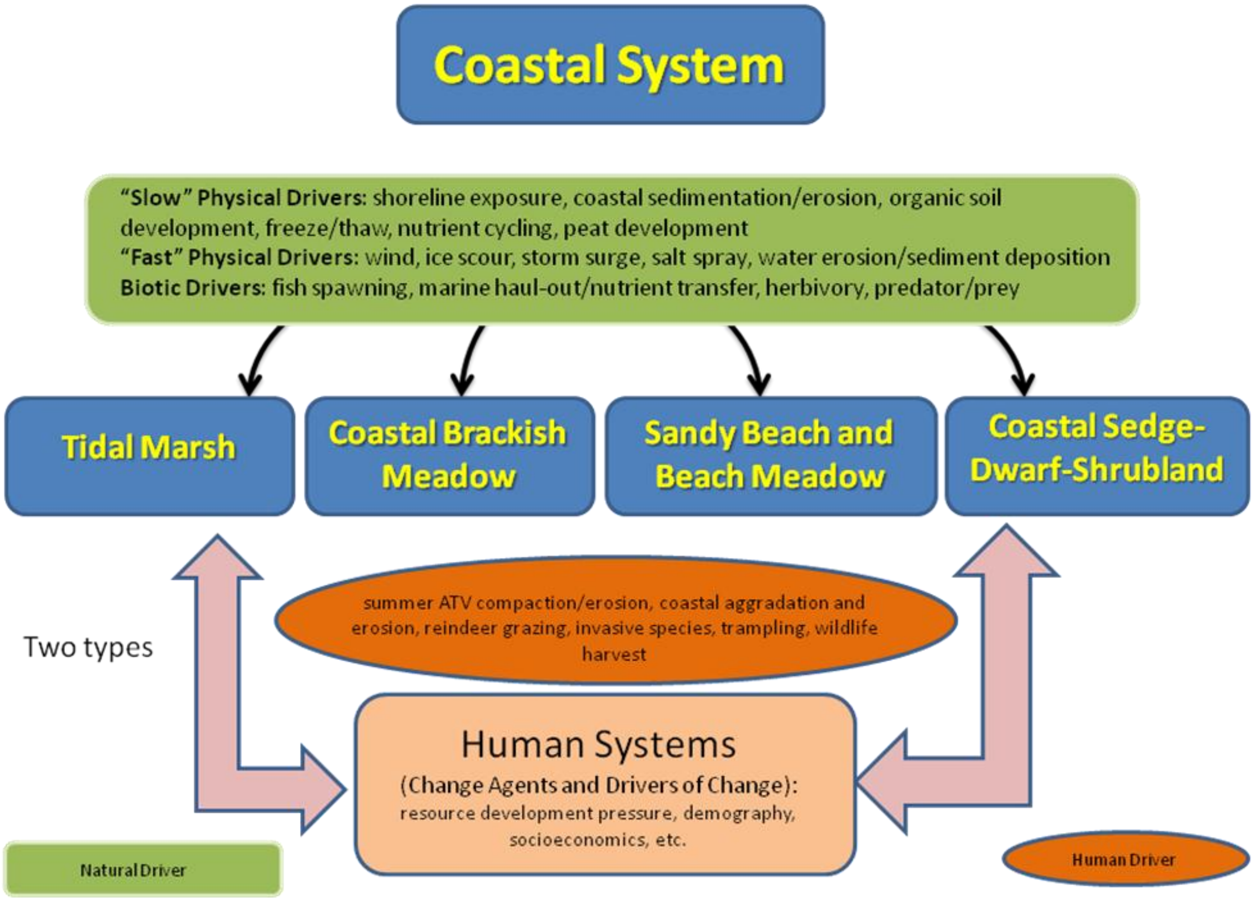
Aquatic systems encompass headwater streams, low-gradient streams, major rivers, estuaries and coastal lagoons, and hot springs, plus the various freshwater lakes that define the aquatic environments for fish and aquatic invertebrates (Figure 2-7). Nine ecosystem types within this category were identified (see Table 2-3 under the Coarse-Filter Elements section). “Slow” physical drivers for these ecosystems include the stream drainage network and connectivity, water chemistry, permafrost development, and subsurface recharge/discharge dynamics. “Fast” physical drivers relate more strongly to seasonal dynamics of snowpack formation and melt, lake turnover, rainfall, freeze/thaw dynamics, and water erosion/sediment deposition. Biotic drivers include food web dynamics, fish spawning, and other predator/prey relationships.

Figure 2-7. Aquatic model components for the Seward Peninsula-Nulato Hills-Kotzebue Lowlands ecoregion.



Coastal systems encompass coastal zones with both upland and wetland vegetation (Figure 2-8). "Slow" physical drivers include shoreline exposure and orientation relative to wind and coastal sedimentation/erosive processes, organic soil development, nutrient cycling, freeze/thaw dynamics, and peat development. "Fast" physical drivers include wind, ice scour, storm surge, salt spray, and water erosion related to freeze/thaw dynamics. Two major coastal ecosystem types were identified: Arctic Coastal Brackish and Tidal Marsh, and Arctic Marine Beach and Beach Meadow (see Table 2-3 under the **Coarse-Filter Elements** section). Biotic drivers for these systems include fish spawning, marine haul-out and nutrient transfer, other food web dynamics, herbivory, and predator/prey relationships.

Figure 2-8. Coastal model components for the Seward Peninsula-Nulato Hills-Kotzebue Lowlands ecoregion.



The human system component of the model is based conceptually on work of Kofinas, Berman, and others (Kofinas et al. 2000, Nicholson et al. 2002, Berman et al. 2004, Berman and Kofinas 2010) in similar regions of the Arctic. People who live in the region rely on wildlife and plants for a large part of their diet and to provide cultural continuity. The following definition of "subsistence" (Alaska Natives Commission 1994), which is broader than hunting and fishing, was adopted for this REA:

> *…activities that require special skills and a complex understanding of the local environment that enables people to live directly from the land. It also involves cultural values and attitudes: mutual respect, sharing, resourcefulness, and an understanding that is both conscious and mystical of the intricate interrelationships that link humans, animals, and the environment. To this array of*

activities and deeply embedded values we attach the word “subsistence”, recognizing that no one word can adequately encompass all these related concepts.

The subsistence use of wild foods is a key CE; thus any CAs that affect wildlife, fish, plants, and access to them also have an impact on subsistence activities. CAs affect communities directly as well -- three in the region are in imminent danger from erosion and are in the process of relocating. Human activity becomes a feedback mechanism in the model. People rely on healthy wildlife populations for food and non-material well-being but human activities also affect ecosystems. Settlement expansion, infrastructure development and decay, mining, energy development, grazing, tourism, and pollution all affect plants, water, and wildlife and are thus all CAs.

2.7 REA Building Blocks: Conservation Elements, Change Agents, and Other Key Features

2.7.1 Conservation Elements

A first step in most natural resource assessments is the identification of the features to provide a focus. One must ask and answer: ***What is it that we wish to evaluate and assess?*** For Rapid Ecoregional Assessments, features that are the targets of assessment are referred to as “conservation elements” (CEs). Key to selection of conservation elements is establishing clarity of purpose. ***What do we need to learn from the assessment?*** For this REA, a two-track focus was used for CE selection. One track focuses on the ecological resources of the ecoregion, supporting regional biodiversity and providing the major ecosystem services. This focus emphasizes assessment of ecological integrity of landscapes and waterscapes. These define the **Core Conservation Elements.** The second track augments the first by including additional values of interest to agencies and stakeholders, such as subsistence species. These define the **Desired Conservation Elements.**

To define the core conservation elements, a “coarse filter/fine filter” approach (Jenkins 1976, Noss 1987, Hunter 1990) was used. This approach has been applied extensively for regional and local landscape assessments since the 1970s. “Coarse-filter” focal ecological resources typically include all of the major ecosystem types within the assessment landscape; the intent is that they represent all of the predominant natural ecosystem functions and services in the ecoregion. If all major ecosystem types are managed and conserved in sufficient area and landscape configuration, the next consideration is how well vulnerable species are “captured” or represented within these major ecosystems and their processes. Those species that are **not** adequately addressed at the ecosystem level are included as additional foci for assessment – the “fine filter.” This approach, therefore, sets up a multi-level focus for assessment.

2.7.1.1 Coarse-Filter Elements

Coarse-filter Conservation Elements for this ecoregion included 32 terrestrial and aquatic ecosystem types that express the predominant ecological pattern and dynamics of the ecoregion (Table 2-3). These classified units a) characterize each of the four components (uplands, lowlands, aquatic, and coastal) of the ecoregion’s conceptual model, b) define the vast majority of this ecoregion’s lands and waters, and c) reflect described ecological types with distributions concentrated within this ecoregion. Ecological systems form different spatial patterns on the landscape. Some ecological systems, such as Boreal Black or White Spruce Forest and Woodland, are a defining and predominant vegetation cover on the landscape in some parts of the ecoregion and therefore can be described as “matrix-forming” – they provide the matrix in which patches of other ecological systems are embedded. Other ecological systems are associated with a suite of abiotic features that occur in more localized or patchy patterns, such as Arctic Active Inland Dunes. Regardless of their spatial pattern and scale on the landscape, all ecological system types were included as coarse-filter CEs to ensure the broadest representation of species found in the ecoregion. The inclusion of the full suite of ecological systems is assumed to adequately represent the habitat requirements of most characteristic native species, ecological functions, and ecosystem services. After reviewing existing national and regional ecological classification products, four existing vegetation maps covering portions of the ecoregion formed the basis for the terrestrial coarse-filter CEs that were identified, while aquatic ecologists with the AKNHP drafted the aquatic coarse-filter types.

Table 2-3. Coarse-filter conservation elements for Seward Peninsula – Nulato Hills – Kotzebue Lowlands ecoregion. Distributions for all 32 coarse-filter CEs were either mapped or modeled.

Map Codes	**Upland Ecological Systems** (13)
3195	1. Arctic Active Inland Dunes
3196	2. Bedrock Cliff, Talus, and Block Fields
4162	3. Boreal Mesic Birch-Aspen Forest
4288	4. Boreal Spruce-Lichen Woodland
4335	5. Boreal White or Black Spruce – Hardwood Forest
5103	6. Arctic Acidic Sparse Tundra
5104	7. Arctic Dwarf-Shrubland
5277	8. Arctic Scrub Birch-Ericaceous Shrubland
5328	9. Arctic Mesic Alder
7166	10. Arctic Lichen Tundra
9901	11. Arctic Mesic Tundra
9902	12. Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra
9908	13. Boreal Black or White Spruce Forest and Woodland
	Lowland Ecological Systems (8)
5276	1. Arctic Mesic-Wet Willow Shrubland
9358	2. Arctic Dwarf-Shrub-Sphagnum Peatland
9376	3. Boreal Black Spruce Dwarf-Tree Peatland
9424	4. Arctic Wet Sedge-Sphagnum Peatland
9903	5. Arctic Shrub-Tussock Tundra
9904	6. Arctic Wet Sedge Tundra
9419	7. Arctic Freshwater Marsh
9900	8. Large River Floodplain
	Aquatic Ecological Systems (9)
	1. Headwater Streams
	2. Low-gradient Streams
	3. High-gradient Rivers (Rivers)
	4. Estuaries
	5. Lakes – Large, Connected
	6. Lakes – Small, Connected
	7. Lakes – Large, Disconnected
	8. Lakes – Small, Disconnected
	9. Hot Springs
	Coastal Ecological Systems (2)
9414	1. Arctic Coastal Brackish and Tidal Marsh
7167	2. Arctic Marine Beach and Beach Meadow

*The map codes assigned to terrestrial coarse-filter CEs are NatureServe ecological system (ESLF) codes; some classes are mosaics, unique to this project, and do not exist in the NS ESLF classification, and therefore were assigned new unique numeric codes in the 9900 range for this assessment effort.

2.7.1.2 Fine-Filter Elements

The “fine filter” includes species that, due to their conservation status and/or specificity in their habitat requirements, are likely vulnerable to being impacted or lost from the ecoregion unless resource management is directed towards their particular needs. Selection criteria for species inclusion and treatment in the assessment included:

a) All taxa listed under Federal or State protective legislation (including species, subspecies, or designated subpopulations)
b) Full species with NatureServe Global Conservation Status rank of G1-G3[1]
c) Full species or subspecies listed as BLM Special Status and those listed in the Alaska State Wildlife Action Plan with habitat included within the ecoregion
d) Important subsistence species

Species meeting initial selection criteria could then be placed into one of two general categories: 1) those that might be effectively treated as a species assemblage – that is, their habitat and known populations co-occur sufficiently to treat them as a single unit of analysis; or 2) those species that are best treated individually. Given the established list of species for the REA, several distinct approaches were used to treat species in the assessment. These included:

- Species assumed to be adequately represented ***indirectly through the assessment of major “coarse-filter” ecological systems*** (Table 2-4). For example, certain subsistence plant species strongly affiliated with certain dwarf-shrubland and peatland systems were treated in the REA through assessment of those shrublands and peatlands themselves.
- Species assumed to be adequately represented ***indirectly as ecologically-based assemblages*** (Table 2-5). That is, due to group behavior and similar habitat requirement, a recognizable species assemblage is defined and treated as the unit of analysis. Examples in this ecoregion include migratory bird stopover sites and marine mammal haul-out sites.
- Species ***best addressed as individuals*** in the assessment. These include those species meeting the criteria for assessment that cannot be presumed to be included in the previous two categories. This includes two subcategories of species:
    - **“Landscape species”** that range over wide areas within the ecoregion and with clearly distinct habitat requirements from all other taxa of concern (Table 2-6)
    - **“Local species”** that have relatively narrow distributions, generally limited to one BLM management jurisdiction. Their numbers are summarized in Table 2-7 and a complete listing is included in Appendix B.
- **Subsistence** species are of critical importance in this ecoregion. Subsistence species important in this ecoregion were identified and then additionally categorized as either landscape or local species (listed in italics in Table 2-4 and Table 2-6.)

This categorization of species shaped the development of both conceptual and spatial models for landscape species (Table 2-6) and ecologically-based species assemblages (Table 2-5). Conceptual models were developed for all species; landscape and some subsistence species received more in-depth treatment. (Conceptual models are compiled in Appendix E.) Existing location information was compiled for local species where available (rare plants and one fish, the Arctic char); maps of predicted habitat were developed for all landscape and subsistence species that were treated individually, as well as all six

[1] See http://www.natureserve.org/explorer/ranking.htm for NatureServe Conservation Status Rank definitions

local bird species. Landscape species (including subsistence species) were all assessed for current ecological status; local species and ecological assemblages were not intended to receive status assessments per memorandum 3 and the work plan. However, an adjustment was made to the terrestrial status assessment input and the status assessments were re-run. Therefore, all six local bird species and the three assemblages received assessments. (Point location data for local plants and fish, and sensitive nature of plant data precluded their inclusion for status assessments.)

Table 2-4. Species addressed through coarse-filter units. Certain plant species were of interest as subsistence species, but they are strongly associated with particular coarse-filter CEs. Therefore, they were assumed to be addressed by these coarse-filter CEs and were not mapped or otherwise assessed individually. Subsistence species are italicized.

Taxonomic Group	Fine-filter CEs Addressed By Coarse-filter CE	Coarse-filter CE That Addresses Fine-filter CE
Plants	*Blueberry, Crowberry/Blackberry*	Arctic Scrub Birch-Ericaceous Shrubland
Plants	*Blueberry, Cloudberry/Salmonberry, Crowberry/Blackberry*	Arctic Dwarf-Shrubland
Plants	*Cloudberry/Salmonberry*	Arctic Wet Sedge-Sphagnum Peatland
Plants	*Crowberry/Blackberry*	Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra
Birds	*Willow Ptarmigan*	Arctic Mesic-Wet Willow Shrubland

Table 2-5. Ecologically-based assemblage CEs and the species which are addressed by them. Distributions for all three assemblages were mapped.

Ecologically-based Assemblage	Taxonomic Group	Fine-filter CEs Addressed By this Assemblage
Waterfowl Breeding Areas* (Migratory Bird Habitats)	Birds	Yellow-billed Loon, King Eider, Common Eider, Emperor Goose
Seabird Colony Sites	Birds	Aleutian Tern
Marine Mammal Haul-Out Sites	Mammals	Pacific walrus, bearded seal, ringed seal, spotted seal

*The original assemblage concept of migratory bird habitat was limited by available data to waterfowl concentration or breeding areas.

Table 2-6. Number and list of species categorized as landscape species. Subsistence species are italicized. Distributions for all 24 landscape species CEs were modeled or mapped.

Taxonomic Group	List of Landscape Species
Birds (8)	Arctic Peregrine Falcon, Bar-tailed Godwit, Black Scoter, Bristle-thighed Curlew, Common Eider, King Eider, Yellow-billed Loon, *Cackling Goose*
Mammals (7)	Alaskan Hare, *Beaver, Black Bear, Brown Bear, Moose, Muskox, Western Arctic Caribou*
Fishes (9)	Alaska blackfish, *Arctic grayling, Pink salmon, Chum salmon, Chinook salmon, Coho salmon, Sockeye salmon, Dolly Varden, Sheefish*
Total (24)	

Table 2-7. Number of species assessed as local species by taxonomic group. Distributions were modeled for the 6 local bird species; existing observation data were compiled and summarized for the local fish and plant species.

Taxonomic Group	# of taxa	List of Local Species
Birds	6	Kittlitz's Murrelet, Red Knot, Emperor Goose, Hudsonian Godwit, McKay's Bunting, Spectacled Eider
Fish	1	Arctic char
Plants	22	(See Table 3-2 for full listing of plant species.)
Total	29	

The following fish species were identified for assessment as landscape species for this REA, but locational data were not available to model their distribution or otherwise assess them:

1. Arctic lamprey (*Lampetra japponica*)
2. Bering cisco (*Coregonus laurettae*)
3. Broad whitefish (*Coregonus nasus*)
4. Humpback whitefish (*Coregonus pidschian*)
5. Pacific lamprey (*Lampetra tridentata*)
6. Pike (*Esox lucius*)
7. Rainbow smelt (*Osmerus mordax*)
8. Round whitefish (*Prosopium cylindraceum*)

Pike is a subsistence fish species; the remainder were not considered subsistence species.

Table 2-8 provides a concise summary by category of conservation elements that were included in this ecoregional assessment.

Table 2-8. Summary of final conservation elements for Seward Peninsula – Nulato Hills – Kotzebue Lowlands ecoregion.

Conservation Element Category	Number of Elements
Upland Ecosystems	13
Lowland Ecosystems	8
Aquatic Ecosystems	9
Coastal Ecosystems	2
Species Assemblages	3
Landscape Species	24
Local Species	29
Subsistence Species (includes subsets of both landscape and local species)	17
Total Number of CEs	**88**

2.7.2 Change Agents

Change agents (CAs) are those features or phenomena that have the potential to affect the size, condition and landscape context of conservation elements. CAs include broad regional agents that have landscape-level impacts such as climate change, fire, and invasive species as well as localized impacts such as infrastructure or extractive energy development. CAs act differentially on individual CEs and may have neutral or positive effects for some CEs, but in general, CAs commonly cause negative impacts. Fire is a natural ecosystem process that contributes to the ecological integrity of fire-dependent or fire-influenced CEs, but fire regimes that have been altered by climate change, active fire suppression, or other anthropogenic influences generally have negative impacts on CEs. CAs can impact CEs at the point of occurrence as well as offsite. Individual CAs can also be expected to act synergistically with other CAs to have increased or secondary effects. All change agents have been reviewed to determine potential impacts to conservation elements, if the impact is currently present, will remain present in the future, or is not present, but considered a future impact. In this assessment, the list of proposed CAs from the AMT was reviewed and a variety of sources were consulted to:

1. Identify additional potential CAs and whether they are currently affecting the ecoregion, are expected to in the future, or both
2. Characterize the ecological effects of each CA
3. Identify potential CEs that could be affected
4. Characterize potential CE impacts from the CAs

Fire, development, invasive species, and climate change are the four major change agents that were identified by the BLM for inclusion in all REAs; these were all confirmed to be highly relevant in the SNK. Insects and disease were recognized as an additional important Change Agent. Invasive species as a change agent was termed as “Non-Native Species,” and insects and disease were termed as “Nuisance Native Species and Diseases” for the purpose of this REA. This decision was based on recommendations from the AMT to identify a species’ nativity with respect to organisms that have known or potential negative impacts to resource management goals. “Diseases” was eventually removed, because a lack of information and data prevented the spatial assessment of this change agent. While permafrost is a physical property or feature of the environment, changes in permafrost will act as a change agent on CEs, and therefore it is grouped with other change agents for the purposes of the SNK assessment. Change agents that were assessed for the SNK REA are:

- Climate Change
- Permafrost
- Fire
- Development (Anthropogenic Activities)
- Non-native Species
- Nuisance Native Species

2.7.2.1 Climate Change

Climate change can be seen as the overarching change agent that governs several others, including changes in fire and permafrost, vegetation and biome composition. Indeed, in Alaska in general, and in the SNK ecoregion in particular, where development is minimal compared to most regions of the US, climate change is a crucially important driver. Climate change is summarized first in this report because of its overarching influence and interaction with other change agents (fire, permafrost).

Climate change is exaggerated in the polar regions, compared to other regions of the globe. This is primarily due to the feedback between warming and albedo – the capacity of the ground surface to reflect or absorb heat. As ice and snow cover disappear, so too do the heat-reflecting properties of those white surfaces, thus increasing the rate of warming (Chapin et al. 2005, Callaghan et al. 2011).

2.7.2.1.1 Climate Trends: Temperature and Precipitation

Climate change, both in terms of temperature and precipitation, is expected to cause stress across the SNK ecoregion, and is expected to act synergistically with other ecosystem stressors. Because this ecoregion is dominated by warm and discontinuous permafrost, changes in temperature could cross the freezing threshold (0° C) and decrease the extent of permafrost. Loss of permafrost may cause changes such as ground slumping or rapid alterations in soil drainage that dramatically affect aquatic ecosystems, species viability, and forage productivity. Seasonal shifts in phenology can cause substantial disruption to existing inter-species dependencies, while potential regional shifts in species range could seriously fragment populations and trigger substantial losses over the coming decades. Inter-annual shifts in both temperature and precipitation could likely alter fire regimes. Climate change is also having and will continue to have substantial effects on Alaska Native communities; one community in the ecoregion is already planning for relocation, and others have been identified as at risk of being severely damaged by erosion or eroding away (due to the combination of higher storm surges resulting from thawing sea ice and the loss of permafrost) (USACE 2009). In addition, changing climate is likely to have effects on many of the wildlife CEs on which the communities depend for part of their food supply, either directly (e.g., through heat stress, drought, or flooding) or indirectly through effects on fire, vegetation, and hydrology.

2.7.2.1.2 Permafrost

Permafrost is an abiotic feature of the ecoregion that is a significant driver of the distribution and character of ecological systems in this ecoregion. Because much of the SNK ecoregion currently has a mean annual temperature just below freezing, the permafrost underlying these areas is highly susceptible to change – complete thaw or partial thaw – under a changing climate regime. Permafrost is not a direct agent of change, but the impacts of ongoing and projected climate change on the extent and character of permafrost in this ecoregion will have cascading effects on hydrology, soil conditions, and drainage (Lloyd et al. 2003), which will in turn affect both aquatic and terrestrial CEs. Climate-driven change in permafrost is moderated by complex interactions among topography, water, soil, vegetation, and snow (Jorgenson et al. 2010). Permafrost thaw, in turn, has profound implications for ecological processes and human uses (Myers-Smith et al. 2008, Daanen et al. 2011, Zhang et al. 2012). The fundamental importance of this defining feature led to its inclusion as a specific focus in this assessment.

2.7.2.2 Fire

The natural fire regime in the SNK ecoregion, in conjunction with other ecosystem variables and processes, has resulted in a mosaic of vegetation of varying stand age, composition, structure, and successional status. However, changes in climate are projected to alter the frequency, extent, and potentially intensity of fire, with consequent impacts on vegetation patterns. Fire regime is a primary driver of landscape-level changes in the distribution of vegetation in the circumpolar arctic/boreal zone (Rupp et al. 2002, Johnstone et al. 2011). Furthermore, vegetation composition and continuity serve as a major determinant of large, landscape-level fires. In the Seward Peninsula region, boreal tree species are expected to invade tundra ecosystems as climate warms (Lloyd et al. 2002), and warming may lead to an increase of over 200% in the area burned per decade (Rupp et al. 2000). Changes in the frequency and extent of fire in Alaska may substantially impact wildlife habitat, including the abundance and quality of winter habitat for caribou (Rupp et al. 2006). In some cases, the combination of climate warming and fire may trigger a shift from forest to grasslands in this region (Rupp et al. 2000).

2.7.2.3 Development

Most of the approximately 18,000 people in the ecoregion live in smaller communities. Nome and Kotzebue are the largest communities in the ecoregion, with populations around 3,600 and 3,200, respectively, as of the 2010 census. Mining is the primary economic activity in the ecoregion. Much of the population is engaged in a mix of wage earning jobs and traditional subsistence practices. Three roads radiate out from Nome; the limited roads present in this ecoregion are primarily seasonal trails or ice roads. Given the small population, remoteness of the ecoregion, and relatively limited economic development, the importance of development as a change agent in this ecoregion is relatively limited.

This CA includes development features that were addressed within the following categories:

- Human population center/community
- Ports
- Trails
- Renewable Energy Fund Sites
- Military (active)
- Roads
- Mines
- Landing strips or airports
- Railroads
- Contaminated sites

2.7.2.4 Invasive Species

Both terrestrial and aquatic invasive species are of management concern throughout the SNK ecoregion. Terrestrial invasive species have the potential to cause large-scale ecological and economic impacts in the state and represent a major threat to the ecological integrity of the ecoregion (Carlson and Shephard 2007). At present, terrestrial invasive species are primarily restricted to anthropogenically disturbed areas in this ecoregion.

2.7.2.4.1 Non-Native Species

Throughout their global range, Norway rats are more common in cold climates and occur in northern latitudes with similar climatic zones to those found in Alaska. Although apparently limited in distribution in western Alaska, the invasiveness potential of this species in Alaska is considered extremely high (Gotthardt and Walton 2011).

The majority of the plant species documented in the SNK are weakly invasive; however, a number of species are moderately invasive (Carlson et al. 2008). *Melilotus alba* is considered extremely invasive and is located just outside the REA boundary, upstream along the Yukon River in Galena (Conn et al. 2008, AKEPIC 2010). The abundance and distribution of non-native plants in Alaska is changing rapidly (Carlson and Shephard 2007, Conn et al. 2008). Increasingly, a greater abundance and diversity of invasive plants and animals are moving off the anthropogenic footprint across Alaska. For most non-native species in Alaska, invasion appears to follow a predictable pattern of introduction to a human population center, followed by dispersal and invasion along road systems, and finally introduction and establishment in natural areas.

Five aquatic non-native species have been documented elsewhere in Alaska; however, no aquatic non-natives have yet been documented in the SNK.

2.7.2.4.2 Nuisance Native Species

Native insects and diseases are also known to cause significant alterations to habitats in Alaska (Patterson 2010). Dominant tree and shrub species across Alaska are subject to damage and increased mortality due to a variety of disease agents (wood decay and canker fungi, root disease, etc.) and native insects (aspen and willow leaf miners, spruce budworm, spruce beetle, northern engraver beetle). Large-scale mortality of dominant boreal trees in Alaska can result in cascading effects on plant communities, wildlife, and even alters salmon spawning habitats (Boggs et al. 2008). Additionally, insect and disease impacts are closely associated with climate. For example, seasonal temperatures above normal are responsible for causing outbreaks of leaf miners and spruce beetles. Thus, interactions between climate change and insects and disease are particularly likely to influence CEs.

Other native species have become pests in aquatic environments. In the last several years, a native diatom, *Didymosphenia geminata*, has blossomed into a nuisance species throughout portions of the U.S. and has drastically reduced native aquatic biodiversity and even altered stream hydraulics (Spaulding and Elwell 2007). *D. geminata* blooms have been observed in many streams around Alaska, primarily on streams that host guided sport fisheries for trout and salmon (D. Bogan and D. Rinella, unpublished), and it is possible that a noxious strain is being introduced by travelling anglers (see Bothwell et al. 2009). In the Kotzebue Lowlands, beavers apparently are re-establishing and have been identified as a nuisance by residents (C. Gregg pers. comm.).

2.7.3 Socioeconomic and Subsistence Context

Other components identified for assessment by BLM specifically for the SNK REA do not fit neatly into the Conservation Element or Change Agent category. The human population of this ecoregion is predominately Alaska Native, who are actively involved in subsistence harvesting as well as the wage economy. This forms an intimate connection between the wildlife CEs of the ecoregion and the human population. The importance of Alaska Native communities in this ecoregion and their reliance on subsistence harvests led to a focus on the socioeconomic and subsistence context of this ecoregion.

2.8 General Assumptions and Limitations

A rapid ecoregional assessment must take advantage of many existing data sets, often applying them for purposes never contemplated by their original developers. This fact, and the strong need for transparency and repeatability, requires careful documentation and management of uncertainty. In order to manage this uncertainty, the REA process included a series of mechanisms for documenting the data sets, information sources, processing steps, and outputs. The steps of this process offer opportunities to manage the inherent uncertainties associated with REAs:

- **Data Documentation.** Throughout tasks 2-3 of the REA, close to one hundred extant data sets were documented in terms of their thematic and spatial precision, accuracy, and completeness, relative to the ecoregion. FGDC-compliant metadata were developed and provided for all data sets ultimately generated in the REA, and the project database provided additional opportunities to capture expert perspective on the relative utility of each data set for the intended modeling purposes of the REA.
- **Repeatability.** Conceptual modeling provides an important mechanism for stating the many assumptions that apply in any complex process. Scientific references used in the REA are provided for easy access by subsequent users. All spatial models include documentation of processing steps, including through ESRI ModelBuilder™ models, so that spatial models may be repeated, analyzed in detail, and updated when new input layers become available.

- **Calibration.** In some instances, during the course of spatial model development, there are opportunities for sensitivity analysis, comparison of similar models, and error documentation.
- **Interpretation.** Finally, inherent in the design of the REA is a series of judgments about the appropriate interpretation of analysis results. For example, the selection of 5^{th} level watersheds and 2 x 2 km grid cells as primary reporting units reflects a judgment about the expected resolution of analysis - based on the resolution of modeling inputs – and appropriate spatial scale for interpreting results. Therefore, it is important to avoid over-interpretation of results. This design aims to limit the potential for misinterpretation by subsequent users.

2.8.1 Limitations: Issues of Scale and Certainty

As remote sensing, GIS, and modeling capabilities have increased along with computing capacity, scale constraints in regional analyses have generally been reduced such that relatively fine-scale mapping and analyses at sub-$mile^2$/$kilometer^2$ resolutions are feasible. However, climate change data, which are a key component of REAs, are still relatively coarse (e.g., 4 km^2 pixel), although available spatial resolution has been improving rapidly. Some other products, such as permafrost models, aim to express effects at broader spatial scales of several thousand acres. Therefore, a variety of scales and resolutions are used in an REA to provide the finest practical and defensible scale of analyses and presentation depending on the source information and available modeling methods and tools.

The fact that an REA is by definition intended to be a rapid assessment utilizing existing data rather than gathering new empirical data creates some important limitations:

- REA results are intended to inform ***landscape-scale direction*** rather than ***site-level decision making***.
- A very large number of analyses were required for this REA, conducted over a short timeframe and therefore modest resources were available for each individual analysis. The REA products are useful for the intended purposes, but they are not comparable to results of focused, multi-year studies on particular management questions.
- Only data considered relatively complete for the ecoregion could be used; therefore, although certain areas of the REA may have had more recent or more precise data, they were not used because they were not consistently available REA-wide.
- Very few source data sets have had rigorous, quantitative accuracy assessments conducted on them; therefore it is infeasible to provide such information for REA results. Instead a qualitative ranking of confidence was defined with BLM to provide information on uncertainty to users, but further consideration of source data quality used in each analysis is encouraged.

3 Summary of Methodology

3.1 Data Management

Data Discovery. Based on the materials developed for Phase I Task 1, NatureServe identified data to evaluate for possible inclusion in the assessment to represent CEs, CAs, and Places (PLs). Working closely with BLM to minimize redundancy in data requests, the responsibility for identifying datasets was assigned to various team members based on areas of expertise. When possible, full datasets were obtained along with all supporting metadata and reports. BLM provided a number of datasets for evaluation and use. As each member of the team obtained and compiled their source datasets, the information was entered in the Master Data List maintained by NatureServe and the appropriate team experts notified so they could begin the data quality evaluation process.

Data Documentation. NatureServe created a secure collaborative workspace for the NatureServe REA project team. A detailed checklist for use by project team members was developed that encompassed the data documentation requirements for each type of data deliverable, from raw source data to those generated as modeling outputs. This has helped ensure that each dataset has the required documentation, including Federal Geographic Data Standards (FGDC)-compliant metadata, models (as appropriate), layer files, and other supporting documentation, as well as adhering to BLM-specified standards for mapping, file formats, and file names.

Data Delivery Mechanisms. Initial data delivery was of "raw" source datasets that were identified by NatureServe as part of the data discovery process. These datasets were delivered in adherence to BLM specified standards and metadata were largely provided "as is" with the addition of BLM keywords. Where no metadata existed, NatureServe created minimal metadata with information about how to obtain detailed documentation for that dataset.

NatureServe delivered to BLM thematic data "packages" that consist of a particular Conservation Element (CE) or Change Agent (CA), Places (PL), or integrated assessment result, along with all of the dependent datasets used as inputs to the creation of the CE or CA. A deliverable package consists of:

- A map document (MXD) with layer groups for the data theme and the related dependent datasets
- All datasets not yet delivered (sources and analysis outputs) with a layer (LYR) file and FGDC metadata attached to the dataset and also as both XML and TXT files
- GIS process models (where relevant) and supporting methods documentation

Map documents and layer files were made available by the NOC through the BLM Data Portal for review, distribution, and storage.

3.2 Models, Methods, Tools

3.2.1 Conceptual Models

Conceptual models were developed to characterize conservation elements and provide a foundation for assessing ecological status. Conceptual models combine text and diagrams in order to describe each CE and clearly state assumptions about its ecological composition, structure, dynamic processes, and interactions with major CAs within the ecoregion. Each model includes a characterization of the CE itself, and how it nests within the four components (upland, lowland, aquatic, and coastal) of the broader conceptual model for the ecoregion. The same basic format was applied with some variation for each of the coarse-filter, landscape species, and ecologically-based species assemblage CEs. The characterization includes a narrative of the CE distribution, relevant life histories for species, and other ecological characteristics. For coarse-filter CEs in particular, characteristic environmental or biophysical setting, landscape dynamics or processes, and dominant or characteristic species are described. Effects of change agents identified for this REA on the CE, as well as effects of other stressors are described. Cited literature and references for each characterization pertains to the CE for its distribution both within and outside the ecoregion. Reference to literature from outside the ecoregion was included where relevant to assumptions being made for CEs within the context of the SNK ecoregion.

The understanding of ecological composition, structure, processes, and relationships to CAs informed the identification of measurable indicators that were used to evaluate the ecological status of each CE. Data and/or model availability determined the selection of indicators as well. Indicators and related information were also documented in the conceptual models. A series of GIS processing steps or modeling approaches were identified to evaluate the indicators for the ecological status assessments of CEs. Ecological status assessments are discussed later in this chapter, in the section **3.2.3.1.2 Ecological Status of CEs: Current**. All conceptual models for individual CEs in this ecoregion are compiled in Appendix E, along with a brief summary of how they were developed.

3.2.2 Distribution Models: Where Are CEs and CAs?

Spatial models are commonly documented in the form of "box-and-arrow" diagrams for each analysis (or category of analyses) to illustrate the data inputs, analytical processes, and model outputs. GIS process models or descriptions explain how distribution was derived or modeled for those CEs and CAs that lacked existing complete or acceptable distribution data. Spatial models for assessments are described in general terms in subsequent sections below and with a high level of detail in Appendix B, in the section **Spatial Modeling of Current CE Distributions**.

3.2.2.1 CE Distribution Models

Distribution was modeled or mapped for all 32 coarse-filter CEs (23 terrestrial coarse-filter CEs and 9 aquatic coarse-filter CEs). Spatial distributions of CEs may be directly mapped using field observation data sets or modeled using a variety of methods. ***Deductive models*** use existing mapped information, and then recombine them according to a set of rules determined by the modeler. Working within ArcGIS, ModelBuilder™ was used to describe interactions among spatial data sets. This contrasts with ***inductive models,*** where most commonly, geo-referenced observations (e.g., known observations of a given species) are combined with maps of potential explanatory variables (climate, elevation, landform, soil variables, etc.), and statistical relationships between dependent variables (observations) and independent explanatory variables are identified and used to derive a new spatial model (Phillips et al. 2004).

CE distributions take several forms in this ecoregion. For most landscape species, spatial distributions were inductively modeled as predicted habitat based on a suite of environmental variables. For one landscape species, the spatial distributions for two distinct habitat components were used: the estimated spatial extent of the winter range and calving grounds were used for the Western Arctic Caribou Herd. Species assemblages and rare plant species were mapped using a range of existing observation data. The distribution of aquatic CEs was mapped or modeled through a variety of means. The current extent of terrestrial coarse-filter units was mapped primarily by mosaicking a series of existing data sets; filters, such as elevation, were then applied to split a small number of vegetation types into separate CEs.

An additional form of spatial modeling relating to CE distributions is climate envelope modeling, where the area within the upper and lower bounds of climate variables (average monthly temperature and total monthly precipitation in this REA) that characterize the current distribution of the CE are identified, and then forecasted to future decades based on the areas that are projected by climate models to be within those upper and lower temperature and precipitation values. These climate envelope models do *not* predict the future distribution of a given CE, *but rather simply indicate the degree and magnitude of potential change in climate regime relative to a particular CE*. Below is a summary of the primary methods used in distribution modeling for CEs.

In many instances for this REA, existing data were derived through inductive modeling of varying forms. For example, Classification and Regression Trees (CART) were used to develop predictive habitat layers for many fish species (e.g., Lowry et al. 2007). Others applied tools such as Maximum Entropy (MaxEnt) modeling for deriving distribution models for individual species (see e.g., Phillips et al. 2006, Elith et al. 2011). Review of existing spatial models led to suggestions for their refinement, which were implemented through deductive methods. In other instances, only deductive, or only inductive methods were used to derive wholly new spatial models. Wherever feasible, final models were validated using georeferenced samples that were not previously used in model development (e.g., in the MaxEnt models for landscape species). Following is a brief summary describing spatial models for each category of CE. Appendix B includes detailed explanations of all spatial models used for CE distributions.

3.2.2.1.1 Terrestrial and Aquatic Coarse-Filter CEs

The terrestrial coarse-filter ecological system CE map is primarily derived by reclassifying the vegetation types identified in the Alaska Natural Heritage Program (AKNHP) land cover mosaic to the corresponding ecological system types described in NatureServe's United States Terrestrial Ecological System Classification. Four regional land cover datasets, plus the National Hydrologic Dataset, were used as the source data for the AKNHP land cover mosaic map. Based on a review of the AKNHP land cover map class descriptions, the majority of AKNHP vegetation classes had a one-to-one relationship with a corresponding NatureServe ecological system. Landfire Existing Vegetation Type (EVT) data were used to burn in the distribution of five ecological system types not mapped in the AKNHP land cover mosaic. Upland, lowland, and coastal variants for seven classes in the AKNHP land cover mosaic were parsed out based on slope, derived from the 60 meter National Elevation Dataset (NED).

The nine aquatic coarse-filter CEs within the ecoregion were mapped or modeled using a variety of source data. A stream network was modeled from the Alaska 60 meter National Elevation Dataset using standard terrain processing/hydrologic modeling methods. *Headwater streams* are defined as 1st and 2nd order streams, *low-gradient streams* are 3rd order and higher with gradient less than 2%, and *rivers* are 3rd order and higher with gradient greater than 2%. *Estuaries*, all salt- and brackish-water marshes, were derived directly from the NOAA Environmental Sensitivity Index (ESI) dataset for Northwest Arctic and Western Alaska. The National Hydrography Dataset was used to identify and classify lakes into four classes: *small and connected lakes, small and disconnected lakes, large and connected lakes, and large and disconnected lakes*. Lakes were parsed by size into small (< 0.1 km2) and large (> 0.1 km2), and then any lake that intersected with the modeled stream dataset was classified as connected. *Hot spring* point locations were obtained directly from the NOAA National Geophysical Data Center Thermal Springs Database.

3.2.2.1.2 Landscape Species and Species Assemblages

Terrestrial landscape species distributions were modeled by the Alaska GAP program (Table 3-1). Element occurrence data and twenty environmental predictor layers were used in Maxent to model species distributions. For migratory species, all occurrences outside the designated modeling season were removed. Only relatively recent occurrence data, from 1990 or newer, and only occurrence data with relatively high spatial accuracy, was used in the modeling. Models were calibrated and validated using standard species distribution modeling methods.

Table 3-1. Distribution of predicted habitat was modeled for local, landscape, and subsistence species by the Alaska GAP Program.

Species	CE Group	Taxonomic Group
Arctic Peregrine Falcon	landscape	bird
Bar-Tailed Godwit	landscape	bird
Black Scoter	landscape	bird
Bristle-Thighed Curlew	landscape	bird
Common Eider	landscape	bird
Red Knot	landscape	bird
Yellow-Billed Loon	landscape	bird
Alaskan Hare	landscape	mammal

Species	CE Group	Taxonomic Group
Emperor Goose	local	bird
Hudsonian Godwit	local	bird
King Eider	local	bird
Kittlitz's Murrelet	local	bird
McKay's Bunting	local	bird
Spectacled Eider	local	bird
Cackling Goose	subsistence	bird
Beaver	subsistence	mammal
Black Bear	subsistence	mammal
Brown Bear	subsistence	mammal
Caribou	subsistence	mammal
Moose	subsistence	mammal
Muskox	subsistence	mammal

Distributions for nine landscape fish species were mapped within the ecoregion using a variety of methods and source data. Distribution maps for five landscape fish species were derived directly by selecting records for all three life stages (present, rearing, spawning) for Chinook salmon, chum salmon, pink salmon, sheefish, and sockeye salmon from the Alaska Department of Fish and Game's Anadromous Waters Catalog (AWC) Species and Life Stages data set. Distribution maps for Coho salmon, Alaska blackfish, Dolly Varden, and Arctic grayling were developed using presence-absence data from the ADF&G Alaska Freshwater Fish Inventory Database (AFFID) and GIS-generated landscape variables in a classification tree analysis.

Distributions were mapped for three species assemblages - marine mammal haul-out sites, seabird colonies, and migratory bird habitats - using a variety of methods and source data. Marine mammal haul-outs and concentrations areas, for bearded seal, ringed seal, spotted seal and pacific walrus, were derived from Audubon's Arctic marine synthesis map and AK GAP occurrence data. Seabird colony sites were mapped from occurrence data, for twenty different seabird species, from the North Pacific Seabird Colony database. The distribution of migratory bird habitats was modeled from a synthesis of important waterfowl breeding sites from five source datasets: Duck and Geese Concentration Areas (TNC Conservation Blueprint), Waterfowl Habitat Areas (ADFG Most Environmental Sensitive Areas (MESA), Audubon Important Bird Areas, and National Hydrography Dataset lakes and ponds that intersected with AK GAP occurrence data (eighteen bird species).

3.2.2.1.3 Local Species

Local species observations were obtained from element occurrence records from the Alaska Natural Heritage Program. (For an overview and detail of Natural Heritage Program methodology, see http://www.natureserve.org/prodServices/heritagemethodology.jsp.) Twenty-two rare local plants (Table 3-2) were summarized by 5th-level watersheds using field observations and/or element observation records.

Table 3-2. List of rare plant species CEs summarized for SNK REA. Four plant species grayed out were not assessed because they were later determined to not be documented within the SNK ecoregion.

Scientific Name	Common Name
1. *Artemisia globularia* ssp. *lutea*	a Boreal Wormwood subspecies
2. *Artemisia senjavinensis*	Arctic Sage
3. *Cardamine microphylla* ssp. *blaisdellii*	Littleleaf Bittercress

Scientific Name	Common Name
4. *Carex heleonastes*	Hudson Bay Sedge
5. *Claytonia arctica*	Arctic Springbeauty
6. *Douglasia alaskana*	Alaska Rockjasmine
7. *Douglasia beringensis*	Arctic Dwarf-primrose
8. *Gentianopsis detonsa* ssp. *detonsa*	Sheared Gentian
9. *Lupinus kuschei*	Yukon Lupine
10. *Oxytropis arctica* var. *barnebyana*	Barneby's Locoweed
11. *Oxytropis kokrinensis*	Kokrines Oxytrope
12. *Papaver walpolei*	Walpole's Poppy
13. *Parrya nauruaq*	Naked-stemmed Wallflower
14. *Potentilla stipularis*	Circumpolar Cinquefoil
15. *Primula tschuktschorum*	Chukchi Primrose
16. *Puccinellia wrightii* ssp. *wrightii*	a Wright's Arctic Grass subspecies
17. *Ranunculus auricomus*	Goldilocks Buttercup
18. *Ranunculus chamissonis*	Glacier Buttercup
19. *Ranunculus glacialis* var. 1	a Glacier Buttercup subspecies
20. *Rumex krausei*	Krause's Sorrel
21. *Smelowskia johnsonii*	Johnson's False Candytuft
22. *Taraxacum carneocoloratum*	Pink Dandelion
23. *Puccinellia vahliana*	Vahl's Alkali Grass
24. *Potentilla rubricaulis*	Rocky Mountain Cinquefoil
25. *Saussurea* cf. *triangulata*	a Saw-Wort
26. *Symphyotrichum yukonense*	Yukon Aster

Six local bird species distributions were modeled by the Alaska GAP program (see section 3.2.2.1.2 and Table 3-1).

The distribution of Arctic char, a local fish species in the Kigluaik Mountains, was mapped using BLM's lake survey data and the National Hydrography Dataset.

3.2.2.2 CEs in Relation to Managed Areas

In addition to above mentioned distribution models that simply indicate where a given CE is likely to occur throughout the ecoregion, a "gap analysis" was completed by overlaying current distributions of all CEs with managed lands. Acreage and proportion of CEs were summarized by major land management categories in the ecoregion.

3.2.2.3 Change Agent Distribution Models

Availability of current and future distribution data for the broad group of CAs was highly variable. Following are general descriptions of approaches for modeling CA distribution. The term "distribution" is used loosely in reference to climate change and fire; those models show the spatial pattern of climate and fire-related variables. Detailed information on the modeling methods used is found in the appendices and in output metadata.

3.2.2.3.1 Climate Trends: Temperature and Precipitation

For this REA, climate change was assessed using downscaled models from the Scenarios Network for Alaska and Arctic Planning (SNAP, www.snap.uaf.edu), with subsets of the available data selected based on the needs of the project (Figure 3-1). SNAP uses modeling to develop plausible scenarios of future climate conditions, and works through a diverse and varied network of people and organizations. SNAP's goal is to allow for better planning for the uncertain future of Alaska and the Arctic.

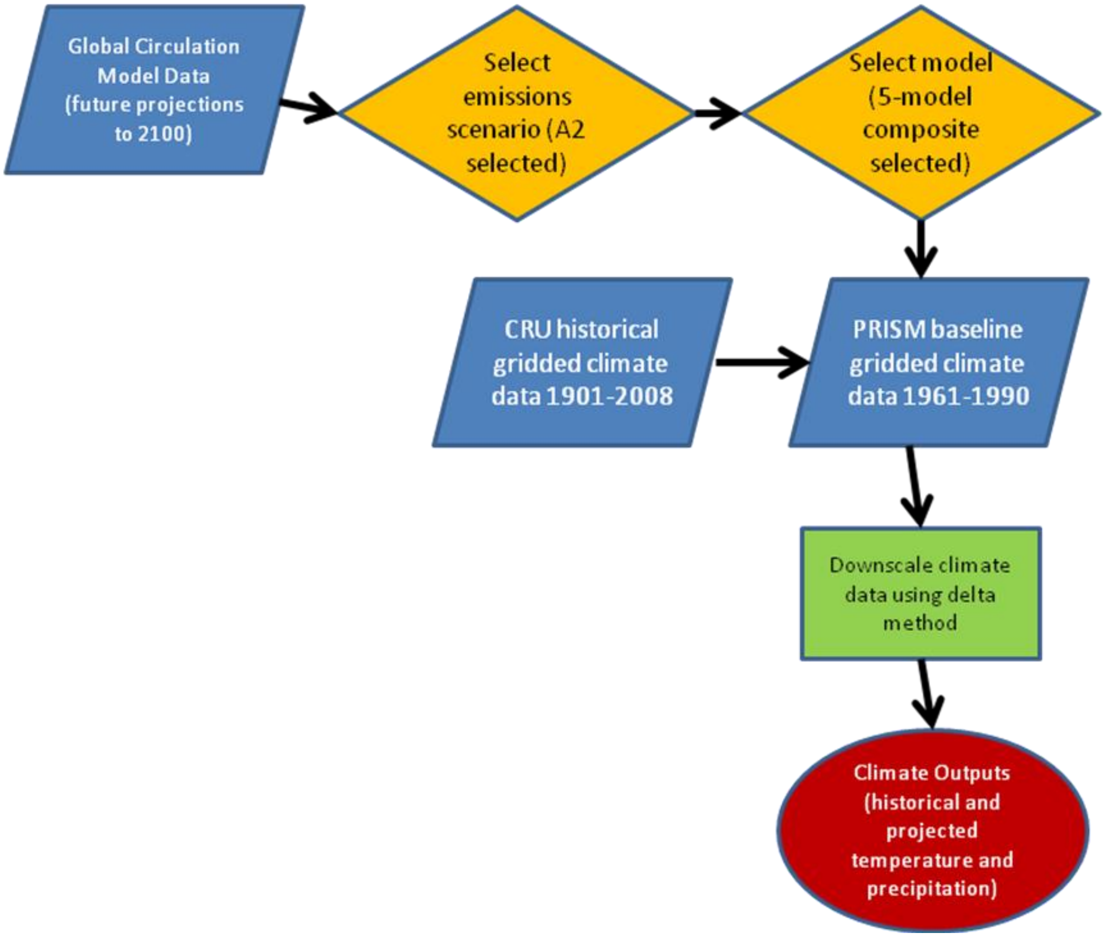
SNAP climate data include both historical datasets, based on gridded values interpolated from climate station data by the Climate Research Unit (CRU), University of East Anglia (http://www.cru.uea.ac.uk/), and future projections, based on Global Circulation Models (GCMs). Both types of datasets have been downscaled using PRISM (Parameter-elevation Regressions on Independent Slopes Model) methodology (http://www.prism.oregonstate.edu/), which takes into account slope, elevation, aspect, and distance to coastlines.

SNAP projections focus on the five available GCMs that perform best in the far north (Walsh et al. 2008). For the projections of future climate for this REA, a composite (average) of all five GCMs was used, in order to minimize uncertainty due to model bias. (The bioclimate envelope models used individual model results and looked for agreement between independent runs; these models are discussed later in this chapter, in the section **3.2.3.1.1 Bioclimate Envelope Modeling**.) SNAP also offers projections for three different emissions scenarios. This project focused on the A2 scenario, which is considered fairly probable, as compared to other scenarios (Anderson and Bows 2008, 2011). Finally, decadal averages were used for evaluating overall climate trends, as opposed to data for single years, in order to reduce error due to the stochastic nature of GCM outputs, which mimic the true inter-annual variability of climate. Thus, the project used climate data for the 2020s rather than just 2025, and used both the 2050s and the 2060s rather than the single year 2060.

A historical baseline period of 1901-1980 was selected in order to maximize the number of years included, while minimizing the inclusion of recent time periods during which climate change trends are already strongly underway.

SNAP's downscaling is performed using the Delta method. This and other methods are described in greater detail in Appendix D.

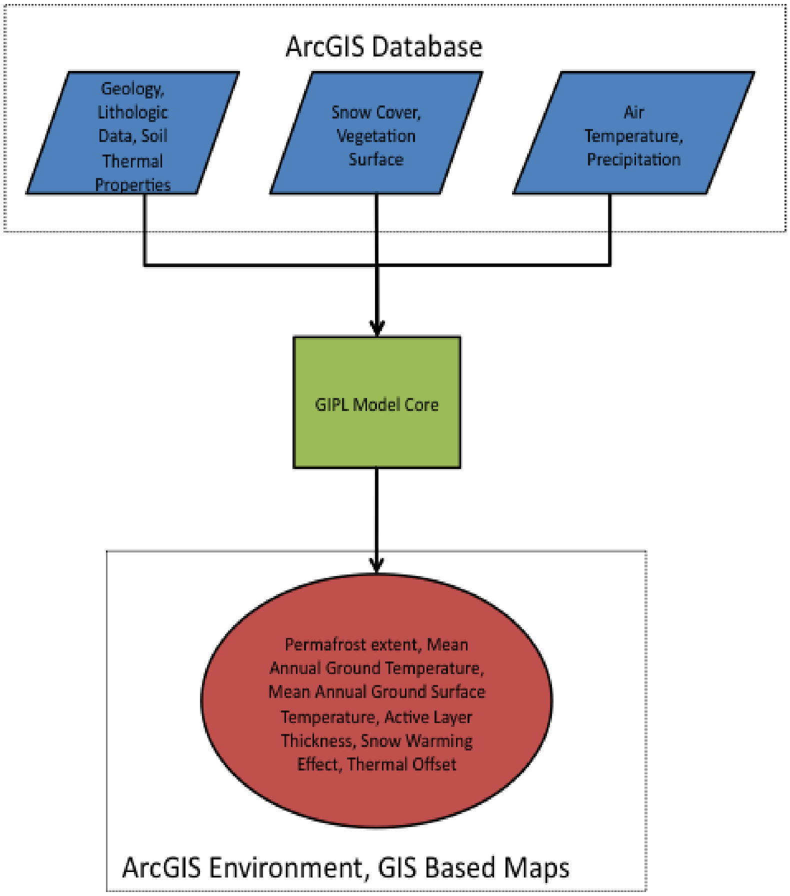
Figure 3-1 Conceptual model of downscaled climate products.



3.2.2.3.2 Permafrost

Permafrost modeling was done using both SNAP climate projections and the Geophysical Institute Permafrost Lab (GIPL) permafrost model for Alaska, which relies upon spatial data on soil, vegetation, and climate (Figure 3-2). Model outputs include mean annual ground temperature (MAGT) and active layer thickness (ALT), linked by appropriate algorithms. Algorithms to determine MAGT and ALT are dependent on calculations of the insulating properties of varying ground cover and soil types, as well as on climate variables, and very spatially across the landscape at a resolution of 1km. Thus, although very fine-scale changes in micro-conditions cannot be accurately predicted by the GIPL model, outputs provide a general picture of areas likely to undergo some degree of thaw and associated hydrologic changes. (For further detail see Appendix A).

Figure 3-2. Conceptual model of GIPL permafrost modeling techniques.



3.2.2.3.3 Fire

The "distribution" of fire was modeled in the larger context of a projected future fire regime and its effects on major vegetation classes. Climate projections, past fire history, and current vegetation patterns were used in part to model patterns of fire frequency across the SNK landscape. The "distribution" of varying fire frequencies is intimately tied to vegetation, as well as climate, but also involves stochastic element such as the exact location of lightning strikes and the variability of weather patterns at finer time-scales than are available to modelers. Thus, multiple model runs yield varying results. Therefore, fire distribution per se was not modeled; rather its projected average frequency across the SNK landscape was used to ultimately model changes in vegetation patterns and distribution. This assessment work is described in a subsequent section in this chapter, **Fire in Relation to Climate and Vegetation**.

3.2.2.3.4 Development

The compilation of data relating to development change agent footprints was relatively straightforward. The following categories of development footprints were compiled for current conditions from a variety of sources:

- Human population center/community
- Ports
- Trails

- Renewable Energy Fund Sites
- Military (active)
- Roads
- Mines
- Landing strips or airports
- Railroads
- Contaminated sites

Future development footprints were mapped for roads, railroads, ports, communities, and recreation (recreation was not part of the current development footprint). Potential future development projects include roads and railroads associated with a proposed port to support a mine, located outside the ecoregion. Roads and railroads were digitized from documents obtained from engineering companies per AMT direction. Ports were digitized at the two proposed sites for a deep water port, at the terminus of the proposed road/railroad corridors. The future relocation site for the community of Shishmaref was digitized from the relocation planning report map. The proposed Salmon Lake Special Recreation Management Area (SRMA) north of Nome was mapped from the BLM's Kobuk-Seward Peninsula Resource Management Plan (KSPRMP) and Environmental Impact Statement. Details on the data sets and processing are provided in Appendix A.

3.2.2.3.5 Non-Native Species

Although invasive, non-native species are an important change agent, data availability is extremely limited. Although the AKEPIC weed observation data are of high quality, a more detailed review led to the conclusion that the data set was too limited to draw conclusions regarding ecoregion-wide impacts on CEs. Therefore, a simple summary and map of those data were developed. This also applies to the single documented location for Norway rat. No aquatic invasive species have been documented in spatial data sets in SNK.

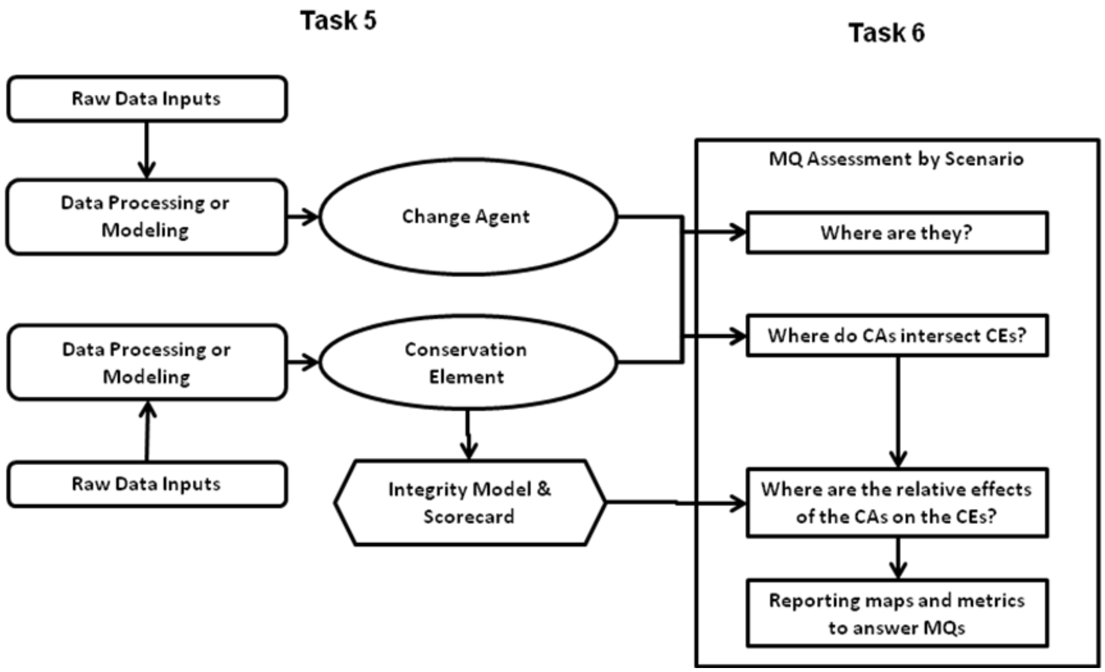
3.2.2.3.6 Nuisance Native Species

Spatial data for nuisance native species is similarly limited. Aerial surveys of insect damage have been conducted and digitized; beetle outbreaks identified in these data are summarized and presented. Diseases were not assessed in this REA due to a lack of adequate information and data.

3.2.3 Assessment Models

An overview of the entire ecoregional assessment model is depicted in Figure 3-3. As noted in the introduction, under the **REA Elements** section, the REAs are ultimately intended to provide an assessment of CEs and CAs and their relationships under the current (2011), near-future (2025), and mid-century (2060) timeframes or scenarios. The characterization of existing CE and CA distributions and conditions on the landscape defines the current (2011) scenario. The current development scenario is intersected with the CEs to characterize the current extent, patterns, and significance of the overlap between CEs and development features. The expansion of development change agents is characterized for a relatively near but uncertain future time (10 to 20 years from now) for this particular REA because the timing of many of the proposed or potential expansion projects is variable and unclear. Development projects have political and funding dimensions that are difficult to predict. This future scenario for development posits the cumulative effects of development CAs as a mix of existing development and proposed or potential development projects. Climate change, fire, and permafrost distributions are modeled both for the 2025 and the 2060 time frame, and effects on CEs under those projections are broadly identified.

Figure 3-3. General conceptual model of rapid ecoregional assessments.



Each component assessment was first proposed as a graphical model specifying inputs, analytical processes (frequently geospatial analyses), and outputs (see memo 3). These models were reviewed by the AMT and revised as needed. Several were prototyped which resulted in further refinement. Where appropriate, models were converted to ESRI Model Builder models to conduct the work and were provided to BLM as specified in the SOW. A number of other modeling tools, such as ALFRESCO and Maxent, were heavily used in this REA and therefore documented by other means, including in the output metadata and in the detailed appendices (A, B and D).

Following the assessment hierarchy of Figure 3-3, modeling methods for these assessments are briefly summarized; further details are presented in the spatial modeling sections of the appendices and in the metadata of assessment outputs.

3.2.3.1 Models of CA Effects on or Intersections with CEs

3.2.3.1.1 Bioclimate Envelope Modeling

Land management and conservation now requires the incorporation of climate change into policy and planning for the management of natural resources. In order to forecast how climate change may result in geographic shifts of climatic conditions for a species of management concern that occupies the SNK ecoregion, its “bioclimatic envelope” must be defined. Species distribution models, also called ecological niche models, are used in this task by correlating known localities of a species’ current range with current climatic conditions. Of course, climactic conditions, such as air temperature and precipitation levels, are not the sole defining characteristics of a species’ occupied range. Nonetheless, climatic conditions play a broad role in determining the suitability of habitat for most species, and they have indirect influence on other factors, such as the extent of certain vegetation communities or the characteristics of local hydrology, that in turn influence habitat availability for species. Thus, there is value for management in anticipating the changes in the geographic extent of suitable climate that climate change may bring. Available data on species known distributions can be combined with forecasts of future climate conditions from climate models to investigate the relative potential impacts of climate change on a given species or ecoregion. This information can serve as one of many inputs in developing an understanding of the direction, rate, and magnitude of potential climate change impact to a species of management interest.

In order to predict how climate change may shift the suitable climatic conditions for a species or vegetation class, its bioclimatic niche is identified by correlating its locality observations with current climatic conditions. The species' modeled bioclimatic niche or envelope can then be projected into the future using downscaled Global Circulation Models (GCMs) to predict where suitable bioclimate may occur at different time slices in 21st century climate scenarios. This information offers one basic building block for a myriad of biogeographical studies that include prediction of extirpation risk, analysis of future conservation priorities and species range shifts.

The species distribution modeling algorithm MaxEnt (Phillips et al. 2006, Phillips and Dudik 2008) was used in conjunction with the historical CRU dataset and the SNAP Climate Projections (both at 2km resolution) to model current and future bioclimate of conservation elements in the SNK region. Maxent is a correlative niche model that uses the principle of maximum entropy to estimate a distribution across geographic space based on the relationship between observed occurrence localities and environmental variables. Maxent was chosen because of its established performance with presence-only data relative to alternative niche modeling techniques, and its built-in capacity to deal with multi-colinearity in the environmental variables used as modeling inputs (Elith et al. 2006, Elith and Leathwick 2009).

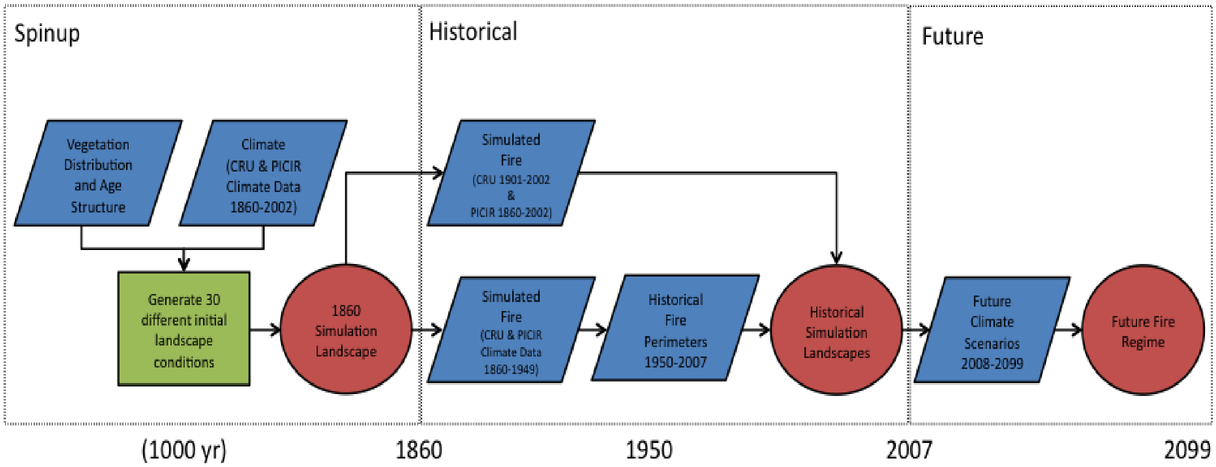
Niche models were generated using the CRU 2km monthly data to define the baseline bioclimatic distribution of each species. Climate change-induced range shifts were estimated with SNAP future climate data, which was comprised of downscaled spatial climate surfaces from five different GCMs (see climate space trends section for spatial climate data details). Each species was modeled with each one of the five GCMs independently. This approach quantifies the degree of agreement across a range of global climate models, thereby offering an assessment of confidence in results. Two time slices were explored, a near-term decade referred to as 2020s (2020-2029) and a mid-century decade, the 2050s (2050-2059). This will complete a time series from 20th century baseline to mid 21st century based on temperature and precipitation.

Results for each species were summarized by comparing the difference between 2050s and current projected distributions across multiple climate model outputs. Change summary maps indicate where at least two of the five GCMs agree on a given outcome. That is, change summary maps display where at least two of five GCMs agree that the bioclimate in a given pixel is an area of potential contraction, expansion, or overlap with the extent of the current climate envelope.

3.2.3.1.2 Fire in Relation to Climate and Vegetation

Potential effects of fire and changes in fire regime were assessed based on historical records, existing literature, SNAP climate data, and simulations performed using Boreal ALFRESCO (Alaska Frame-Based Ecosystem Code). ALFRESCO (Rupp et al. 2000, Lloyd et al. 2002) simulates the responses of subarctic and boreal vegetation to transient climatic changes, and has been previously used in the Seward Peninsula region. ALFRESCO simulates fire and successional dynamics based on five major subarctic/boreal ecosystem types: upland tundra, black spruce forest, white spruce forest, deciduous forest, and grassland-steppe. The model is generally calibrated through use of a "spin-up" period of 1000 years of simulated fire history, in order to match outputs as closely as possible to historical fire patterns (Figure 3-4). However, due to model limitations for this region, calibration had to be modified, resulting in outputs that are pertinent for regions of tundra and regions of spruce-dominated forest, but less pertinent for shrubby deciduous areas. For further information on ALFRESCO, see Appendix A.

Figure 3-4 Conceptual model of ALFRESCO fire simulation methodology.



3.2.3.1.1 Overlap of Development CAs with CEs: Current and Near Future

Once the current development change agent footprints were compiled, they were aggregated into a single layer for use in evaluating their overlap with CEs. A similar aggregation was completed for the combined current and potential development footprints to create a future development scenario. After generation of CAs and their aggregation into a current and a future scenario, CAs and CEs were intersected to answer the initial part of MQs asking where and to what degree CAs may co-occur with CEs. Statistics on the area and proportion of the CE overlapped by each CA and total area and proportion of the CE overlapping with all specified CAs were calculated and provided. Outputs include the option to develop maps of each CE distribution with areas of CA intersect indicated with a separate value for the overlapping CA(s). One challenge with the future development footprints is that multiple alternatives are under consideration for the major development projects. For example, two locations for a deep-sea port are being considered. Multiple routes for roads to support the port and the Ambler mine are under consideration. Currently, there is no clear information on which of the options is likely to be selected. Therefore, per BLM and AMT, the future footprint for development change agents incorporated all of the likely options, which over-represents the overlap that will be experienced by CEs.

3.2.3.1.2 Ecological Status of CEs: Current

Beyond reporting on the potential co-occurrence of development CAs and CEs, relative effects of those co-occurrences are primarily addressed by gauging ecological status of CEs within a given assessment scenario (e.g., current 2011 conditions). The method for assessing ecological status of individual CEs was derived from existing methods for evaluating relative ecological integrity. NatureServe's ecological integrity framework (Faber-Langendoen et al. 2006, Unnasch et al. 2008, Rocchio and Crawford 2011) provides a practical approach for identifying, organizing, and evaluating measurable indicators for this purpose. The ecological status of a coarse-filter CE is characterized by its ability to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion; this ability is partly dependent on ecological processes (e.g., hydrologic regime, fire regime, nutrient cycling, storm events, or insect outbreaks) that define or act upon the system operating within their natural range of variability.

In the SNK ecoregion, a combination of two major factors informed the identification and selection of measurable indicators that were eventually used to assess the status of CEs:

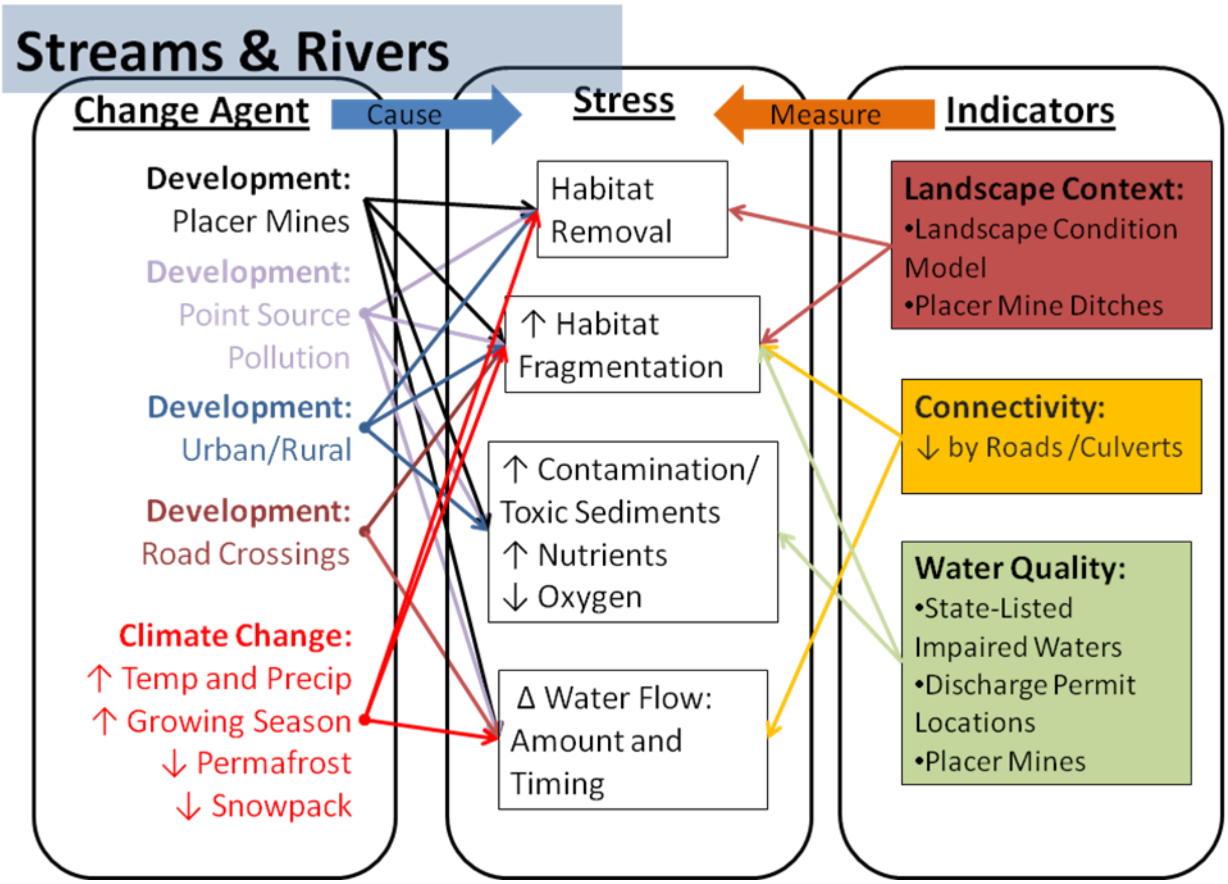
1. the characterization of reference conditions, processes, stressor impacts, and other factors that are known or expected to affect the ecological status of CEs, as documented in the CE conceptual models (compiled in Appendix E), and
2. the availability of adequate, spatial data and appropriate methods or modeling tools that could be readily applied within the REA to measure the indicator and report it in a spatially explicit manner using the 5th level watershed and 2 x 2 km pixel reporting units selected for this ecoregion.

While the conceptual models provide a summary of the major aspects of condition, processes, and change agents that define or act upon a CE, data are not available to characterize every single aspect of a CE's condition, composition, structure, supporting processes, and influences by all change agents, particularly at the level of individual CEs. In general, geographically and thematically comprehensive, field-observed data for any *direct* indicator of ecological status for the CEs (e.g., species composition, vegetation structure, water quality, etc.) is not available for this ecoregion. Spatially explicit data are available for direct anthropogenic stressors (e.g., roads, culverts, contaminated areas, mines). Therefore, the indicators identified for assessing ecological status of individual CEs were stressor-based, rather than direct measures of ecological status.

The indicators identified for each CE were organized into **key ecological attributes** (KEAs), or ecological drivers. Key ecological attributes (KEAs) may include natural characteristics, such as native species composition, ecosystem processes, such as hydrologic regime, or stressors, such as effects of change agents that are known to impact the natural function and integrity of the CE. The KEAs are typically organized by the three **rank factors** of **Landscape Context**, **Condition,** and **Relative Extent**. This hierarchical framework for ecological *integrity* provides a structured "scorecard" for reporting on the ecological *status* of a given CE within a given location, and also facilitates the aggregation and synthesis of ecoregionally significant component indicator results for characterizations of integrity at coarser scales. (Methods for characterizing the ecological *integrity* of the ecoregion as a whole are discussed in the subsequent section in this chapter, **3.2.3.2 Ecological Integrity of the SNK Ecoregion.**) The indicators, KEAs, and related information were also documented in the conceptual models for each CE.

Figure 3-5 illustrates an example of the conceptual linkages between CAs and stressors, and the indicators used to gauge stressors for stream CEs in the SNK ecoregion. The primary reporting unit for ecological status of terrestrial landscape species and coarse filter CEs was the same 2 x 2 km grid used for the climate change analyses; for the aquatic CEs, the 5th level watersheds were the reporting unit.

Figure 3-5. Example of a conceptual diagram linking change agents, ecological stressors, and their anticipated effects for an aquatic coarse-filter CE.



For both terrestrial and aquatic CEs, Relative Extent could not be assessed because information on the historical extent of the types that were mapped is not readily available for the vast majority of CEs identified for this ecoregion.

For terrestrial CEs, four indicators were considered (Table 3-3), two were selected for assessment in memo 3 and the work plan, and only one was eventually applied to individual terrestrial CEs: the Landscape Condition Index. Invasive plants, the second indicator specified in memo 3, were dropped as an indicator of condition after further review of the comprehensiveness of the data at the fifth AMT workshop.

Fire and climate change are the two dynamic ecosystem processes (and change agents) that were also modeled for the SNK REA to address a variety of management questions. Several substantial data and model limitations precluded using these models to inform the assessment of the ecological status of *individual CEs*; consequently, these models were not proposed for this purpose for the SNK REA. Instead, the ALFRESCO model results provide information on significant changes in four broad categories of vegetation present in the SNK ecoregion (upland tundra, black spruce forest, white spruce forest, and deciduous forest) that are projected as a result of projected changes in both climate and fire frequency; these results are discussed in the Future Conditions chapter in the Fire section. The projected climate trends provide an overall indication of the significance and nature of expected change, without reference to individual CEs, while the bioclimate envelope models indicate where suitable climate is likely to be available to those CEs in the future.

ALFRESCO was selected as the most suitable available tool for assessing the potential interacting impacts of changing climate and fire regimes on vegetation. It is currently designed to only look at broad categories of vegetation; re-working the entire model to address finer divisions of vegetation (e.g., the individual terrestrial coarse-filter CEs mapped in this REA) would be a years-long process. In addition, given the relatively coarse resolution of information on fire regimes in relation to vegetation, there would likely be such a high degree of uncertainty regarding model outputs for more finely divided vegetation classes that such a re-working of the model would not be useful, at least in the foreseeable future.

Table 3-3. Indicators *or* ecological processes that were initially considered for use in status assessments of terrestrial CEs.

Rank Factor: Landscape Context
Key Ecological Attribute: Landscape Condition
Indicator: Landscape Condition Index
Rank Factor: Condition
Key Ecological Attribute: Condition
Indicator: Invasive Plant Index
Indicator/Process: Fire Regime
Indicator/Process: Insects and Diseases

For aquatic CEs, nine potential indicators were initially considered and another was added late in the REA process (Table 3-4). Of the original nine, data for hydrologic regime and reference aquatic biotic condition were known to be lacking. Non-native plant species were dropped as noted previously for terrestrial CE indicators. No state-impaired waters or fish stocks of concern had been identified within the SNK ecoregion at the time of the assessment.

Table 3-4. Indicators that were initially considered for use in status assessments of aquatic CEs. Indicators shown in bold font are the final set that were possible to assess given available data.

Rank Factor: Landscape Context
Key Ecological Attribute: Connectivity
Indicator: Index of Fish Passage (Culverts)
Key Ecological Attribute: Surrounding Land Use Context
Indicator: Landscape Condition Index
Indicator: Non-native Species (Terrestrial Plants)
Indicator: Placer Mine Ditches
Rank Factor: Condition
Key Ecological Attribute: Surface Hydrology
Stream gage or other hydrologic data not available

Key Ecological Attribute: Water Quality
Indicator: State Impaired Waters (none present in SNK ecoregion)
Indicator: Alaska Pollution Discharge Elimination Permits
Indicator: Placer Mines (added later)
Key Ecological Attribute: Aquatic Biotic Condition
Reference conditions for aquatic biotic condition not established; data not available
Fish Stocks of Concern (none present in SNK ecoregion)

Table 3-5 provides an overview and brief description of the final set of indicators that were used to assess ecological integrity for both terrestrial and aquatic CEs, including a brief description of the data and methods used to assess the indicators. Spatial datasets on the final set of indicators were analyzed to characterize the ecological status of individual CEs using a variety of spatial models. These indicators were applied in varying combinations for each CE. For this REA, as noted previously, the data available even for simple stressor-based indicators greatly limited the number of potential *measurable* indicators. Not all of the three rank factors had measurable indicators; for example, Relative Extent could not be assessed for any CEs because it requires spatial data on the historical extent of CEs to compare to their current extent. Numerous other indicators could theoretically be identified for use in assessing ecological status of individual CEs. However, the availability of relevant data in the SNK ecoregion greatly constrained the indicators that could actually be assessed. All indicators identified in memo 3 and the work plan for this REA are included here, with the exception of the terrestrial invasive species index. The invasive species index was the second of two indicators identified for terrestrial CEs, and it was removed per discussions in AMT 5 due to the very limited geographic extent and small number of surveys (six), and total number of observations relative to the ecoregion. State-impaired waters were a third indicator of water quality for aquatic CEs; however, review of the impaired waters listings showed there are no impaired waters in the SNK ecoregion. Similarly, there are no fish stocks of concern within the SNK ecoregion to inform aquatic biotic condition. In addition to Table 3-5 below, Appendix E includes a listing of indicators assessed for each CE.

Table 3-5. Overview of indicators used to assess ecological status for terrestrial and aquatic CEs. At the highest level, the indicators are organized under the rank factors of *Landscape Contex*t and *Condition* (blue-shaded heading rows). Within those rank factors, they are further grouped by Key Ecological Attributes (gray-shaded heading rows). All five indicators are calculated or indexed to have scores ranging from 0 to 1, with 1 being the highest possible score and indicating the best status for the indicator.

Indicator	Definition and Scoring	Justification
Rank Factor: Landscape Context		
Key Ecological Attribute: Landscape Condition / Surrounding Land Use Context		
Landscape Condition Index	This indicator is measured by intersecting the mapped area or habitat distribution map of the CE with the landscape condition layer and reporting the average LC index value for the CE or habitat within each 5th level watershed for aquatic CEs, or 2x2 km grid cells for terrestrial CEs. Landscape Condition Index is a 30-meter resolution map surface that incorporates a land use intensity rating and a distance decay function, reflecting decreasing ecological impact with distance from the source. The results are a score for landscape condition from 0 to 1, with 1 being very high landscape condition and values close to 0 having very poor condition.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance.
Index of Placer Mine Ditches	This indicator of surrounding land use is measured by summing the total length of placer mine ditches (NHD) within each HUC; this indicator is applied to individual aquatic CEs. The total ditch length per watershed is converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score.	Historical land uses, such as placer mine ditches, may continue to impact the surrounding landscape and affect CEs.

Indicator	Definition and Scoring	Justification
Key Ecological Attribute: Connectivity *(Aquatic species CEs and aquatic stream CEs only)*		
Index of Fish Passage (culverts)	This indicator provides a measure of relative stream connectivity in terms of fish passage. The total count of culverts partially or completely restricting fish passage was tallied per HUC and applied to all fish CEs and riverine coarse-filter types. The number of culverts per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score.	The relative degree of landscape or stream network connectivity affects the movement of individuals of a species, potentially constraining access to critical habitat resources.
Rank Factor: Condition		
Key Ecological Attribute: Water Quality *(Aquatic CEs only)*		
Index of Placer Mines	This indicator is calculated by the number of intersections a CE has with placer mine footprints; placer mines were assumed to have five-acre footprints. Each intersection event received a value of 1 and the total number of mines was summarized by HUC. The number of CE-mine intersections per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score.	Unremediated placer mining affects stream habitats by leaving behind unstable and incised streambeds that lack riparian vegetation (Densmore and Karle 2009). This decreased stability in streams with historic placer mining activity leads to high suspended sediment loads during spring snowmelt and summer rainstorms (Pentz and Kostaschuk 1999), which may impact fish spawning success downstream.

Indicator	Definition and Scoring	Justification
Pollution Permits	This indicator estimates the relative integrity of water quality conditions in individual water bodies based on the number of pollutant permits issued through the Alaska Pollutant Discharge Elimination System (APDES). According to the APDES, *A pollutant may be any kind of industrial, municipal, or agricultural waste discharged into water. Pollutants include sewage, solid waste, chemical wastes, biological materials, seafood processing wastes, dredged soil, mining wastes, rock, sand, dirt, munitions, heat, garbage, discarded equipment, and runoff from construction or agricultural sites*. The list of APDES permits by community was summed by HUC. The number of permits per watershed was converted to a normalized score (between 0 and 1) by the following formula: 1-(indicator value/maximum value) where 0 = worst or highest degree of impact and 1 = best or least impacted score	Polluted water negatively affects aquatic species health and ability to successfully reproduce. This indicator is an indirect measure of pollutants.

3.2.3.2 Ecological Integrity of the SNK Ecoregion

A simple, overall index of ecological integrity was desired to summarize conditions in the ecoregion. The original thinking was to identify a method for aggregating individual status scores for groups of CEs within the ecoregion. As described in memo 3:

> For example, there may be one overall terrestrial coarse-filter CE status score, based on the summed per-pixel value of the landscape condition layer overlain on their combined distribution. [The aggregation of these status scores would provide one ecoregional measure of integrity.] Separately, there could be an overall score for 2-3 aquatic coarse filter CEs within the watershed, with their composite score based upon the relative proportional contribution of each aquatic CE in that watershed. Finally, a landscape species score might be derived from the component status scores of the several species with distributions in the watershed, proportionally calculated. [Similarly, the aquatic and landscape species score aggregations would similarly provide two more ecoregion-level indicators of integrity.]

However, testing of these methods and review of the results in other REAs highlighted significant concerns about the usefulness and appropriateness of aggregating various scores by groupings of CEs. Therefore, as a starting point in the SNK ecoregion, each of the indicators was directly summarized across the entire ecoregion to provide a set of *spatially explicit*, summary indicators of integrity.

The sole spatially explicit indicator relating to terrestrial ecological integrity is the Landscape Condition Index. Landscape condition was also used as indicator for aquatic CE status assessments. Landscape condition, aquatic connectivity, and the placer mine, ditch, and pollution permit indicators were summarized by 5th-level watershed to provide summary indicators of integrity relating to aquatic systems at the ecoregion level.

In addition to summarizing spatially explicit indicators identified for the CE status assessments at the ecoregion level, the results of the climate and fire modeling conducted for this REA are used to qualitatively describe the likely influences of those processes on current and projected ecoregional integrity. These pieces of information are then integrated to provide a qualitative, overall discussion of ecoregional integrity for the SNK ecoregion.

3.2.3.3 Socioeconomic and Subsistence Assessments

Small populations are difficult to model, particularly with insufficient data and over relatively long time horizons. In addition, socioeconomic data available for this ecoregion are typically obtained through surveys and generally compiled in tabular format or in descriptive reports; other than the footprints of the communities in this ecoregion, the socioeconomic and subsistence data and information is non-spatial. The socioeconomic and subsistence assessments for this REA use simple and transparent methods: presenting and synthesizing available data, and using literature and personal conversations with a wide range of experts to understand, synthesize and interpret the findings. Data include commonly used, publicly available sources, such as US Census and ADFG subsistence harvest surveys, as well as survey data that are not publicly available. Most of the literature used in this study is unpublished reports, such as ADFG community harvest studies, newspaper articles, and reports from individual research grants. These data and methods are in contrast to other components of this REA, which relied largely on geospatial analysis or other modeling of spatially explicit data sets.

Expert assistance for this component of the SNK REA came from James Magdanz ADFG; Dave Koster ADFG, Ed Ward, Manilaaq Inc., Scott Goldsmith ISER, Suzanne Sharp ISER, Virginia Fay, ISER, Alejandra Villalobos-Melendez, ISER, Ron Dailey Dowl Engineers, Chris Harrington, Dowl Engineers, Peter Bente Army Corps of Engineers, Bryant Hammand, Kawerak Inc., Michael Brubaker ANTHC, and Robert Loeffler, ISER (former director of Alaska Division of Mines).

4 Current Conditions in the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion

Throughout the Current Conditions chapter, the Potential Future Conditions chapter, and Appendices A, B, C, and D, the management question(s) being addressed in a particular section are highlighted as in this example below, with the original MQ number included for reference:

> **147**: What are the potential future climate scenarios for temperature and precipitation?

4.1 Current Socioeconomic Profile and Conditions

This section addresses the management questions highlighted here. Management questions often have multiple parts; portions of questions that are displayed in gray text are addressed in other sections. Here, the portion of MQ 16 relating to how the communities might change under development and climate change scenarios is addressed in the Future Conditions chapter, under the **Projected Socioeconomic Profile and Conditions** section. The portion of MQ 10 relating to subsistence species is covered in this chapter as part of the species CE distributions section, **4.3 Distribution of Conservation Elements**. This entire section provides an overview of current socioeconomic conditions for communities in the SNK. Details on individual communities (e.g., demographic charts of age-sex structure for individual communities) as well as more background on data used to develop this content are provided in Appendix D.

> **16**. (a) What is the current socio-economic profile for each community? (b) How are they likely to change under development and climate change scenarios?
>
> **10**: What are the current ranges of subsistence species? Where are the subsistence communities?

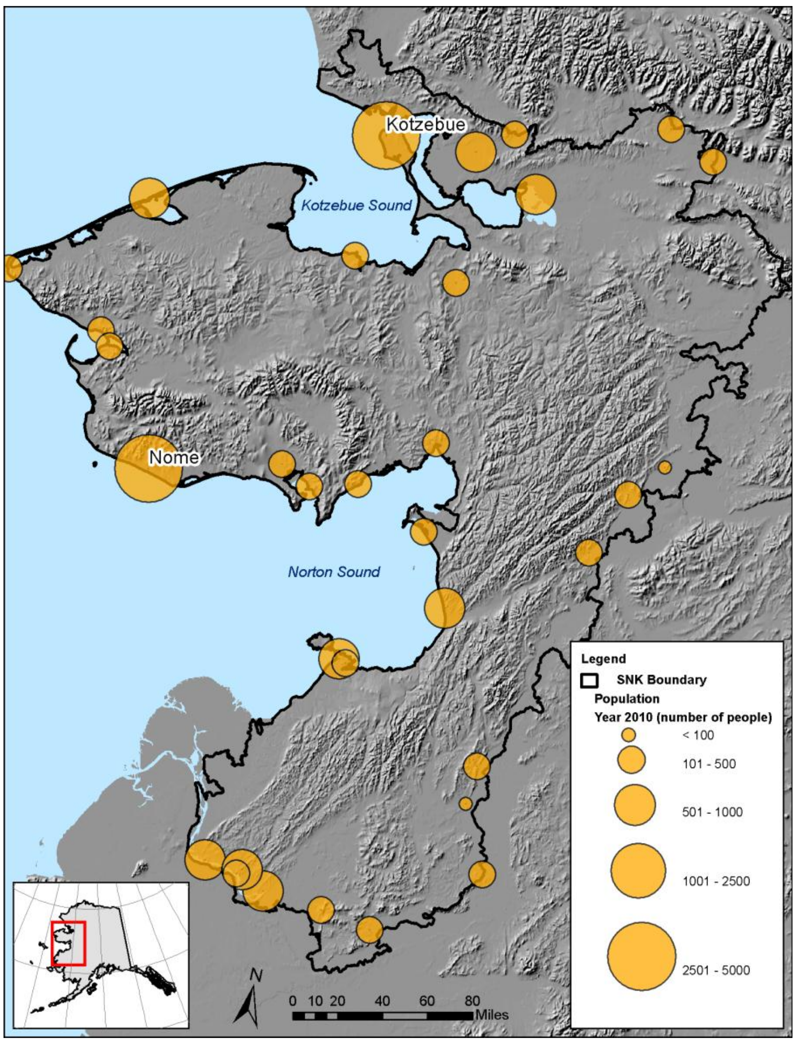
4.1.1 Overview of Socioeconomic and Subsistence Data and Information

Small populations are difficult to model spatially or empirically, particularly with insufficient data and over relatively long time horizons. In addition, socioeconomic and subsistence-related data available for this ecoregion are typically obtained through surveys and generally compiled in tabular format or in descriptive reports; other than the footprints of the communities in this ecoregion, the socioeconomic and subsistence data and information is non-spatial and often qualitative. The socioeconomic and subsistence assessments for this REA use simple and transparent methods, synthesizing and interpreting available data, literature, and conversations with local and non-local experts to characterize current socioeconomic conditions and assess subsistence MQs. These data and methods are in contrast to other components of this REA, which relied largely on geospatial analysis or other modeling of spatially explicit data sets. Although the data, information, and methods used rely on some degree of qualitative interpretation, the assessment team has a reasonable degree of confidence in the information and synthesis presented for the assessment of **current** socioeconomic conditions. The variability in how subsistence harvest data have been collected and recorded over time allow only a fair to moderate degree of confidence in the characterization of subsistence-related MQs. Details on data sets and other information used for the socioeconomic and subsistence-related assessments are highlighted in Appendix D.

4.1.2 Population and Demographic Structure

Approximately 18,000 people live in 33 communities in the SNK ecoregion. The regional centers, Nome and Kotzebue, have populations of 3,500 and 3,200, respectively (US Census 2010). The boundaries of the ecoregion do not coincide with political boundaries. The two types of political boundaries, Alaska Native Claims Settlement Areas (ANCSA) and borough/census areas, are closely tied to language/cultural groups. Borough and census area boundaries coincide with ANCSA regions. The ecoregion covers parts of 4 ANCSA regions (parts of 1 borough and 3 census areas). Most people live in villages with populations ranging in size from 85 to 830 individuals (US Census 2011; Figure 4-1). Villages average 95% Alaska Native. Nome and Kotzebue have lower proportions of Alaska Natives. Nome is 66% Alaska Native[2] and Kotzebue is 81% Alaska Native. The large share of non-Natives in Nome dates from its beginning as a gold rush town. Communities are located primarily along rivers and the coast for access to fish and mammals, and more recently, for barge access to bring in fuel and supplies. Because there are no roads, fuel, food, construction materials, appliances and other household goods, heavy equipment, cars and trucks, and nearly all other non-perishable goods are all brought in to communities by barge. However, places that have access to fish and mammals and are located for easy barge access are often exposed and vulnerable to harsh weather conditions.

Figure 4-1. Location and 2010 population size of communities in the SNK ecoregion.



[2] Alaska Native includes Alaska Native alone (1 race) and 2 or more races categories from US Census 2010.

Local economies are a hybrid mix of subsistence harvesting, wage work, and government transfers[3]. The mixed economy is seen in aboriginal communities around the Arctic (Kruse et al. 2008) and is persistent over time. Wage earnings are higher in Nome and Kotzebue than in villages. In 2010, transfers made up about 15% of total person income (ISER estimate using BEA 2012).

Flexibility is the key to Alaska Native resilience. It is reflected in thousands of years of working together, seasonal harvests of wide ranges of species, and strong traditions of sharing among households. Subsistence, wages, and transfers provide households with a diverse economic base. As such, the mixed economy is a source of community resilience. However, nearly all communities in the SNK region are experiencing major disruptions, directly or indirectly due to climate change.

4.1.3 Wage Employment and Income

Within the SNK ecoregion, employment patterns in villages are different than in regional centers. Villages have a very small private sector and nearly all jobs depend on government spending. Local government and the schools are the largest employers, making villages highly vulnerable to changes in state and federal programs. Even though schools are major employers, some places have few students and only three or four school jobs. Unemployment in some villages is as high as 60%. Of the people with jobs, few have year-round full-time work (AKDoLWD 2012). Employment is also higher in some ANCSA regions/boroughs than others. The Red Dog zinc mine in the Northwest Arctic Borough (NWAB) is jointly owned by the NANA native corporation and Tech, Inc. and has a hiring preference for NANA shareholders. Data indicate that the Red Dog mine[4], located in the Northwest Arctic Borough, and Community Development Quota (CDQ) program[5] in coastal communities increase job opportunities and increase earnings. NWAB villages have the highest proportion of people aged 16 or older who are employed and the highest per worker earnings (AkDoLWD 2012). Villages that are part of the CDQ program have the next highest share.

AKDoLWD reports the number of residents ages 16 and older who are working in full-time or part-time jobs. These data do not include self-employed workers and are not reported for individual small communities. They are reported for Kotzebue and Nome, then within each borough/census area for all villages grouped together (Table 4-1). For regional centers, the data show slow growth in the number of people who have full-time jobs. Over the five years from 2002 to 2008, Kotzebue added 15 jobs and Nome added 37 jobs. Except for villages in the Northwest Arctic Borough, villages have lost jobs. The biggest losses were in the Yukon-Kuskokwim region, which had 57 fewer jobs in 2008 than in 2002.

---

[3] Transfers include social security, unemployment insurance, Temporary Assistance to Needy Families (TANF), Supplemental Nutrition Program for Women, Infants and Children (SNAP), and the Alaska Permanent Fund dividend.

[4] Red Dog mine is owned by NANA Corporation and Teck, and has preferential hire for NANA shareholders. Red Dog employs about 220 NANA shareholders (Haley 2010). However, not all shareholders who work for Red Dog live in the region. Direct jet service from Anchorage to Red Dog mine allows workers to commute from the Anchorage/MatSu area.

[5] The Community Development Quota Program (CDQ) is a federal program started in 1992 which allocates 10% of fisheries quota harvest shares in the Bering Sea among 6 CDQ organizations stretching from the Bering Strait to the Aleutian Islands (NRC 1999). CDQs range in size from 1 to 20 communities. The goal is to provide employment, income, and development opportunities for 65 Bering Sea coastal villages (located within 50 miles of the coast).

Table 4-1. Change in full-time employment 2002-2008.

Community	5 year change in number of full-time jobs	% change
Kotzebue	15	2%
Nome	37	3%
Bering Straits villages	-6	-1%
NWAB villages	8	1%
Wade Hampton villages	-28	-4%
Yukon-Koyouk villages	-57	-5%

Source: AKDoLWD 2008.

4.1.4 Cost of Living: Increases and Impacts

Global fuel prices have magnified impacts in rural Alaska. Heating fuel and gasoline cost more than twice as much in the SNK region as in urban Alaska. Food prices and the cost of transportation in and out of villages have increased sharply over the past five years. Fuel prices are projected to rise faster than in urban Alaska because of increasing difficulties and costs of getting barges into communities (Szymoniak et al. 2010). Along the Noatak River, the summer river depth in recent years has been insufficient to allow for annual delivery of fuel by barge. As a result, all of the fuel for the communities of Ambler and Shungnak and other communities outside of the ecoregion are shipped in by airplane (NANA undated). Community residents sometimes offload fuel from barges onto small boats to bring it in. In worst cases, fuel is flown in, or in the case of Nome in 2011, brought in with a tanker and ice-breaker. High food prices mean people are forced to rely more on subsistence foods, but the cost of fuel used to get to hunting areas makes subsistence very expensive as well.

There is some evidence that the increasing cost of living has led to increased out-migration (Lowe 2009, FAI 2009), threatening the viability of very small communities. Over the past 10-20 years, in many communities, out-migration has been higher than natural increase, leaving small communities with few young adults, and more men than women. In general, more communities have been losing population than gaining, and small places have been losing population fastest. However, concern for the future of rural Alaska is not new. Writing nearly 40 years ago, Alonso and Rust (1976) studied the high rates of out-migration from rural area and asked, “What is becoming of village Alaska?”

4.1.5 Current Climate Change Effects on Communities

Some communities are already being directly affected by flooding, erosion, and/or permafrost thaw resulting from climate change, causing buildings to collapse and infrastructure to fail. In the case of Shishmaref, which is located on Sarichef Island (a barrier island chain along the northern Seward Peninsula), erosion is forcing the entire community to relocate. Because most infrastructure is connected, failure in one location can affect the entire community. Flooding, erosion, and permafrost thaw also dislodge pollutants, such as naturally occurring mercury as well as sewage and dump waste, contaminating the water supply and creating health hazards (ANTHC 2012). Thawing of traditional food cellars makes some subsistence foods unsafe to eat. Earlier ice break-up and later freeze-up has made travel on the ice more dangerous. After freeze-up, people switch from using boats to using snow machines to access hunting areas. River ice needs to be thick enough and extensive enough for safe travel. During freeze-up neither boats nor snow machines are useful because of too much ice for boats but not enough ice cover and depth for snow machines. According to the Arctic Climate Impact Assessment (Huntington and Fox 2005), the timing, quality of ice, speed of complete freezing, associated weather, and ecological effects all combine to produce the many and varied impacts of a late freeze-up.

Hunters use shore-fast ice as a platform for hunting. It is particularly important for access to bowhead whales (George et al. 2004). Besides making hunting more dangerous, lack of shore ice leaves communities vulnerable to storm surges, which erode community infrastructure. Winds pile up slow-forming ice, making travel hazardous (Huntington and Fox 2005). Rivers have become wider and shallower, making them harder to navigate and limiting hunter access to wildlife. Increased fire has also affected subsistence harvests by damaging caribou habitat and fallen trees are blocking trails. Winter habitat of caribou requires 80–100 years to recover because of the slow post-fire re-growth of lichens, the primary caribou winter forage (Kofinas et al. 2010). However, fire has increased moose habitat (Kofinas et al. 2010). In some places, permafrost thaw has damaged access roads to waste dumps, and people have been reported dumping waste in other places and creating new trails to dumps, and damaging tundra (ANTHC 2012).

4.2 Current Subsistence Conditions

Given that subsistence practices and lifestyles are integral to Native communities throughout this ecoregion, numerous MQs relating to subsistence were identified for this REA. The subsistence-related MQs can generally be grouped into three categories:

- What are current subsistence harvests like?
- What might they be like in the future?
- How might a particular factor (e.g., regulatory framework) be likely to affect or change harvests in the future?

Subsistence-related MQs that address current conditions or conditions in the recent past are addressed here in this Current Conditions chapter and are highlighted below. Additional information on these questions, particularly data sets used to answer the questions, is provided in Appendix D, in the **Subsistence Assessments** section.

> **28:** What types of traditional and local knowledge data exist for the region and how can these data be best incorporated into management decisions?
>
> **6**: Which species make up the largest share (lbs.) of subsistence harvests? How is this changing?
>
> **4**: How much have harvests (lbs.) changed over the past 20 years?

Subsistence questions that ask how harvests *could* change are addressed in the Future Conditions chapter. Additional questions on how various factors might affect subsistence conditions in the future are also provided in the **Subsistence Assessments** section of Appendix D.

4.2.1 Traditional and Local Knowledge

> **28:** What types of traditional and local knowledge data exist for the region and how can these data be best incorporated into management decisions?

Traditional and local knowledge consists of the holistic understanding of relationships and interactions among plants and animals (including humans) present in a local environment with the environment itself. This knowledge is based on direct observation or experience of these interactions and events and is transferred from one generation to the next. Its value is derived in part from the continual, intimate connection between the human observer and the environment. Cultures who generate and embody this knowledge don't see themselves as observers, apart from the environment, but as one of many integral components of the ecosystem as a whole. In the SNK ecoregion, this body of knowledge among Native communities includes things like an understanding of seasonal patterns of storm events, snow and ice melt in streams and rivers, timing and patterns of freeze and thaw on rivers, streams, and the nearshore ocean environment, local seasonal and annual permafrost dynamics, local fire history and patterns, timing and patterns of fish spawning, timing, pattern, and pathways for animal movement or migration (e.g., moose, caribou), and phenology of other events critical to the life histories of plants and animals on which the communities depend. To the extent that elements of this body of knowledge are shared outside of Native communities, it can be used to inform interpretation of data collected using western methods, such as ADFG's subsistence harvest data.

Since 1978, ADFG's subsistence division has been conducting community-level case studies. ADFG is mandated to conduct harvest surveys and report traditional and customary use practices in each community. Local and traditional knowledge and seasonal harvest rounds are well documented in these studies. Most are case studies of individual or small groups of communities. They are available as technical reports on the ADFG website. Project Jukebox at UAF has recorded oral histories, which are available at http://jukebox.uaf.edu/site/projects Alaskool.org. Anthropological studies document traditional and local knowledge (Huntington, Krupnik, Burch, Langdon, Cruikshank among others) and are published as ethnographies.

Traditional and local knowledge does not generate data, so most studies are not maintained in a database format. Chukshank (1998) warns against parsing tradition and local knowledge into data. However, some efforts are underway to link traditional knowledge to maps. Alaska Native Health Tribal Consortium (ANTHC) has started a program using local observers to record unusual events[6]. The data are stored in a spatial database, but the project has not operated long enough to have a sizable amount of information. North Pacific Research Board (NPRB) Bering Straits Local and Traditional Knowledge (LTK) program has linked traditional knowledge to harvests by asking about harvests and observations in the same survey. However, these data are not publically available.

Local knowledge is place-specific and is about what is currently happening or has happened in the past. It is not predictive (Krupnik and Jolly 2002). Huntington et al. (2006) describe differences between native and western ways of thinking: Athabascans view humans as an integral component of nature in which the respect that people have for nature influences the probability of biophysical outcomes. Western science tends to view people as apart from nature with human impacts on ecosystems occurring purely through biophysical mechanisms. Traditional knowledge contains spiritual elements that are not part of western scientific method. For many Alaska Natives, because traditional spiritual beliefs are an essential part of subsistence practices, and talking to non-Natives about those beliefs is forbidden, not all elements of subsistence are open for discussion. Traditional and local knowledge has been described as seeking to understand "How?" while western science attempts to characterize "Why?" (Kofinas 2002). Both are needed to understand complex problems.

In addition, verification of traditional knowledge can be problematic. For example, in Alaska Native communities, elders are highly respected and it is considered inappropriate to contradict them or ask for clarification. Nadasdy (1999) notes the importance of power dynamics in native knowledge transmission. Huntington et al. (2006) discuss the importance of context for understanding local and traditional knowledge and the need to be cautious in interpreting information.

Alaska Native participation is essential for decision making. "This is not a matter of consultation, voicing opinions, or perfunctory 'participation.' It instead requires that Native peoples be in the driver's seat,

---

[6]Michael Brubaker, who leads the project, will provide data to the REA group for use in future REAs. They are currently working on the ISER data request.

proposing and adopting concrete institutional, organizational, and managerial solutions that reflect their own diverse preferences, cultures, circumstances, and needs" (Cornell and Kalt 2003). Participation, especially from people who live in very small communities, is not easy. Alaska Natives are overloaded by the number of requests for participation and knowledge sharing, most efforts to engage participation of Native peoples are inadequately funded, and in some cases public meetings are not the appropriate venue (Gallagher 1986). A short list of agencies and organizations requesting local participation includes school boards, state and federal wildlife management agencies, species-oriented co-management organizations, local and tribal governments, regional governments, ANSCA for profit and non-profit entities, village corporations, and visiting research projects. Kofinas (2002) recommends several ways to include communities in decision-making:

- Establish co-management boards. However, problems with co-management boards are that agendas are often overrun with policy questions instead of resource sustainability and high subsistence users are usually not part of the board because they are too busy hunting and fishing.
- Require local knowledge to be officially part of the decision making process. Include elders and local experts in decisions and pay honoraria for their participation.
- Build organizational capacity, by hiring local people.
- Document local knowledge.
- Share local knowledge with scientists and back to community.
- Promote awareness and stewardship, by encouraging local people to observe their environment, and develop ways to record and maintain their observations.

In this report, local and traditional knowledge substantially informed responses to the following management questions:

- **2**: How could changes in sea mammal harvests potentially affect land based hunting and fishing?
- **7**: Given current and estimates of future subsistence species populations, are harvest regulations adequate to protect subsistence species populations?
- **9**: How have hunting and fishing regulations affected general hunting and fishing harvests?
- **11**: In which locations are climate change events likely to affect subsistence species?
- **28**: What types of traditional and local knowledge data exist for the region and then how can these data be best incorporated into management decisions?
- **44**: How are transporters/tourism/sport hunt and fishing affecting the migration patterns of caribou?
- **106**: How have the reindeer herds changed over time? How do herds affect grazing areas?

Local and traditional knowledge helps to understand data. It also helps to describe possible responses to changes in the availability of subsistence foods. For example, local and traditional knowledge also helps understand why some game management regulations are inappropriate or ignored. Bag limit restrictions and calendar openings and closings are at odds with subsistence hunting. In each community, a few hunters harvest most of the animals and then share with the community. High gasoline prices make hunting for only a few animals prohibitively expensive. Calendar openings and closings often do not match well with the availability of animals, river conditions or ice thickness. In many cases, subsistence hunters ignore restrictions that don't fit with subsistence needs. As a result, people are sometimes reluctant to participate in harvest surveys because they're not sure if they were hunting out of season, or especially in the case of birds, harvesting protected species.

4.2.2 Characterization of Subsistence Harvests

This section focuses primarily on management question 4 and the first part of management question 6.

> **4**: How much have harvests (lbs.) changed over the past 20 years?
>
> **6**: Which species make up the largest share (lbs.) of subsistence harvests? How is this changing?

Where there are sufficient data to compare across years, harvest totals vary considerably from year to year but generally indicate that harvests have decreased over the past 20 years – both in terms of total pounds of edible meat harvested and edible pounds per capita. During the late 1980s and early 1990s, per capita harvests ranged from 600-1000 pounds per person. More recent surveys show about 450 pounds per person. The biggest changes have been weak salmon runs since the late 1990s and increases in caribou harvests since the 1970s. The Western Arctic Caribou Herd increased in size to nearly 500,000 animals in the early 2000s and extended its winter forage range onto the Seward Peninsula in the mid-1990s. However, the caribou harvest may drop again because the herd is smaller (325,000 in 2011 (Woodford 2012)) and migration to the winter range is later.

However, subsistence foods continue to be a large part of household food consumption. According to the Survey of Living Conditions in the Arctic, subsistence foods make up between half and three-quarters of all food consumed by Alaska Native households (Martin 2005). High-income households are also high subsistence-producing households, and have been termed “super households” (Wolfe et al. 2009). Wolfe et al. (2009) identified what has become known as the “30:70 rule,” where 30% of households produce 70% or more of a community’s subsistence food. Even though only 30% bring in the bulk of the hunt, nearly everyone reports using subsistence foods, illustrating widespread sharing and the role of the hunter as part of a much larger system. Subsistence traditions connect people to each other, the animals, and land over thousands of years. This is especially true of Alaska Natives who are among the only aboriginal groups in the world that have not been displaced from traditional lands (Magdanz et al. 2010).

Subsistence species vary from community to community and from year to year. Each community has a particular seasonal pattern in which one harvest follows another; signals about what to harvest next come from tradition and what people observe about the animals, changes on the land, and the weather during the current harvest. The seasonal round varies from year to year due to river conditions, ice, weather, migratory patterns, species abundance, technology, economic opportunities, and other factors (Georgette and Loon 1991).

Seals, fish, moose and caribou make up the largest share of harvests in the ecoregion. All coastal communities in the SNK ecoregion harvest seals. Seven communities in the region harvest walruses and are members of the Eskimo Walrus Commission: Brevig Mission, Nome, Shishmaref, Kotzebue, Stebbins, Unalakleet, and Wales. Some places also harvest Beluga whales. Per capita harvests vary widely but in the Bering Straits region harvests average about 250 pounds per person for seals and 350 pounds per person for walruses (Ahmasuk et al. 2008). Wales is the only community in the SNK ecoregion with a bowhead whale harvest. It is one of nine community members of the Alaska Eskimo Whaling Commission (AEWC) and receives an annual whale harvest quota. However, Wales does not successfully harvest bowhead whales every year. A bowhead whale contributes 24,000 pounds of edible meat. Bowhead harvests are shared widely among communities; every community surveyed in the Bering Straits region reported using bowhead whale. Coastal and inland communities within or near the Western Arctic Caribou Herd (WACH) range report several hundred pounds per person of caribou. Inland communities in the northern part of the SNK region report caribou, moose, and fish as the largest shares of subsistence harvest. Communities along the Yukon River report fish and moose as making up the largest share of harvests.

4.2.3 Limitations of Harvest Survey Data

Since 1978, ADFG's subsistence division has been doing community-level case studies. ADFG is directed by statute to conduct harvest surveys and report traditional and customary use practices in rural communities. Most are case studies of individual or small groups of communities. ADFG collects harvest information from each household in a community (or a random sample of households). Harvests, attempts, and use are reported by species by community, rather than by specific harvest location. In some cases, species reported in a community were not harvested near there. For instance, people from Shishmaref sometimes travel to Wales to assist with bowhead whale harvests. Not all species are included in all surveys and only a few communities in the state are surveyed each year. Most of the complete harvest surveys that are included in the database were done in the 1980s and 1990s. From these surveys, ADFG has created a community-level harvest database and issued technical reports, which are available on their website[7]. The ADFG database covers 29 years from 1980 through part of 2009. However, for communities in the SNK ecoregion, the most recent data are for 2004. Many ADFG technical reports present data from comprehensive surveys, but the data are not included in the ADFG database (Ahmasuk 2008, Magdanz 2002, Magdanz et al. 2010), because not all survey data have been reviewed, coded, and merged with the statewide data. The variability in surveys from year to year and the incomplete integration of existing survey data with the statewide data set make it difficult to develop a complete and accurate picture of subsistence harvests that can be compared across years or decades. This is part of the reason for the importance of using traditional and local knowledge to help characterize subsistence harvest conditions. Additional details on data sets used for the subsistence assessment are highlighted in Appendix D.

4.3 Distribution of Conservation Elements

This section addresses the management questions highlighted here; the questions all ask, in essence, where are the CEs located. The portion of MQ 10 shown in gray text relating to the locations of subsistence communities is covered earlier in this Current Conditions chapter, in section **4.1 Current Socioeconomic Profile and Conditions**; see also Figure 4-1).

60: What is the current distribution of each CE?

10: What are the current ranges of subsistence species? Where are the subsistence communities?

113: Where are the important aquatic resources, such as spawning grounds and other fish habitats? (herring spawning grounds and areas used by waterfowl?)

Tundra and sub-Arctic boreal forest and woodland ecosystems characterize the SNK ecoregion. This REA included a broad selection of CEs representing the ecological systems and key species of the ecoregion and this section provides brief answers to management questions pertaining to their spatial distribution. The conservation elements in this assessment include a number of terrestrial and aquatic ecosystems (the coarse-filter CEs), and individual landscape species. Other species were assessed as components of species assemblages. All of the CEs were spatially mapped within the ecoregion, with the exception of the eight fish species for which locational data were not available. Results of CE of distribution modeling

[7] ADFG subsistence harvest website: www.adfg.alaska.gov/index.cfm?adfg=subsistence.harvest

or mapping are illustrated with examples of high-interest CEs that will be used throughout this report. Complete results for all assessed CEs can be found in Appendix B.

The overall distribution of terrestrial coarse-filter CEs is shown in Figure 4-2 and their proportions in the ecoregion are summarized in Table 4-2. Spruce and aspen forests and woodlands are concentrated in the Nulato Hills part of the ecoregion and comprise approximately 20% of the ecoregion's vegetative cover. Although present throughout the ecoregion, shrublands and tundra ecosystems are predominant on the Seward Peninsula. Different shrubland types are concentrated in the Kotzebue Lowlands as well. Herbaceous and dwarf shrub tundra types cover approximately 35% of the ecoregion; another 30% is classified as shrubland types, some of which are also part of the tundra ecosystem (per Table 4-2). Peatlands cover nearly 6% of the ecoregion, and numerous lakes, streams and other open water cover another 4%. The distributions of 1) Arctic Scrub Birch Ericaceous Shrubland (upland); 2) Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra (upland); 3) Arctic Shrub-Tussock Tundra (lowland); and 4) Arctic Mesic-Wet Willow Shrubland (lowland) are shown in Figure 4-3 as examples of the distributions of upland and lowland types that are predominant in significant portions of the ecoregion.

Figure 4-2. Terrestrial coarse-filter ecological systems of the SNK ecoregion.

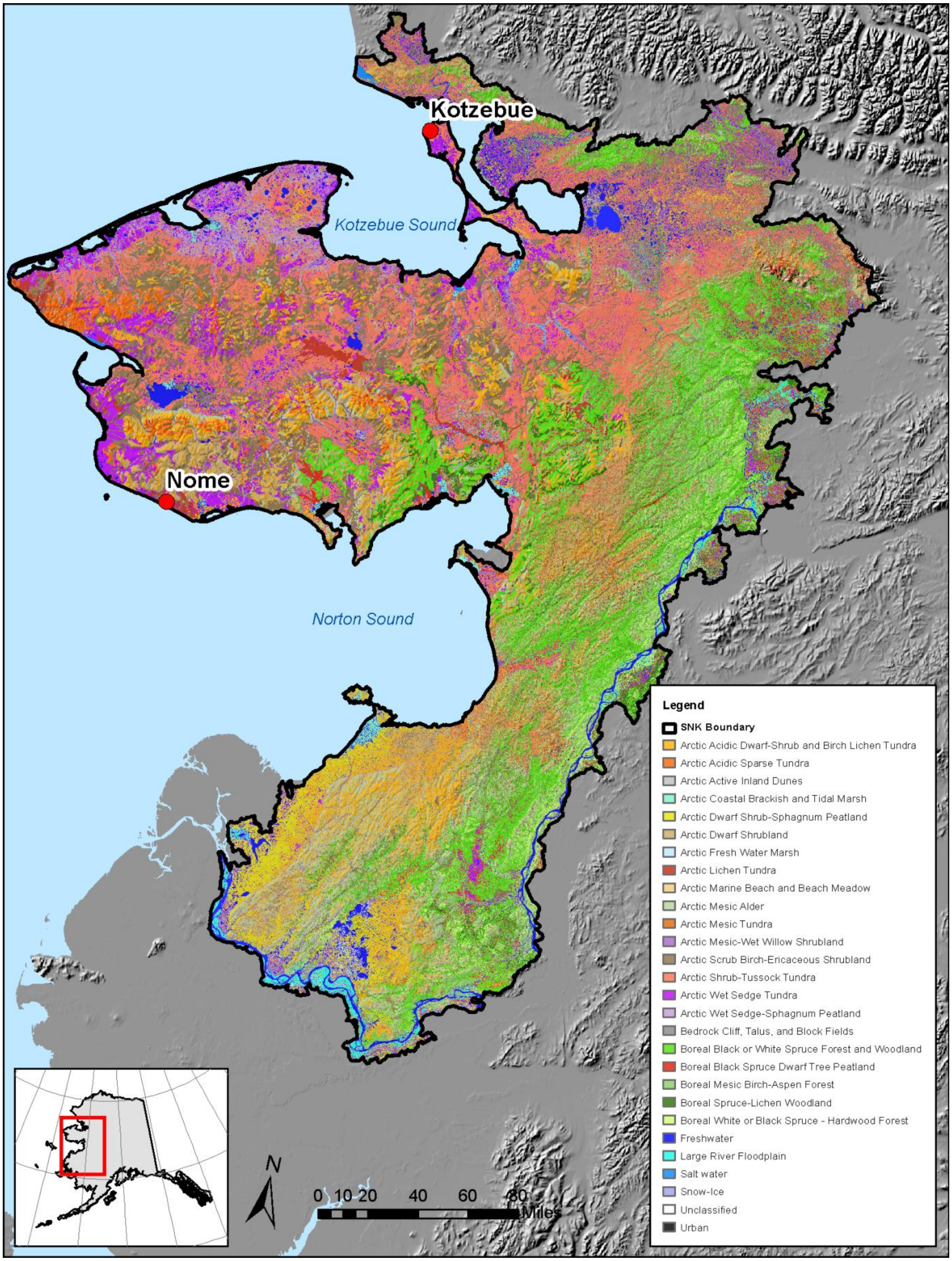
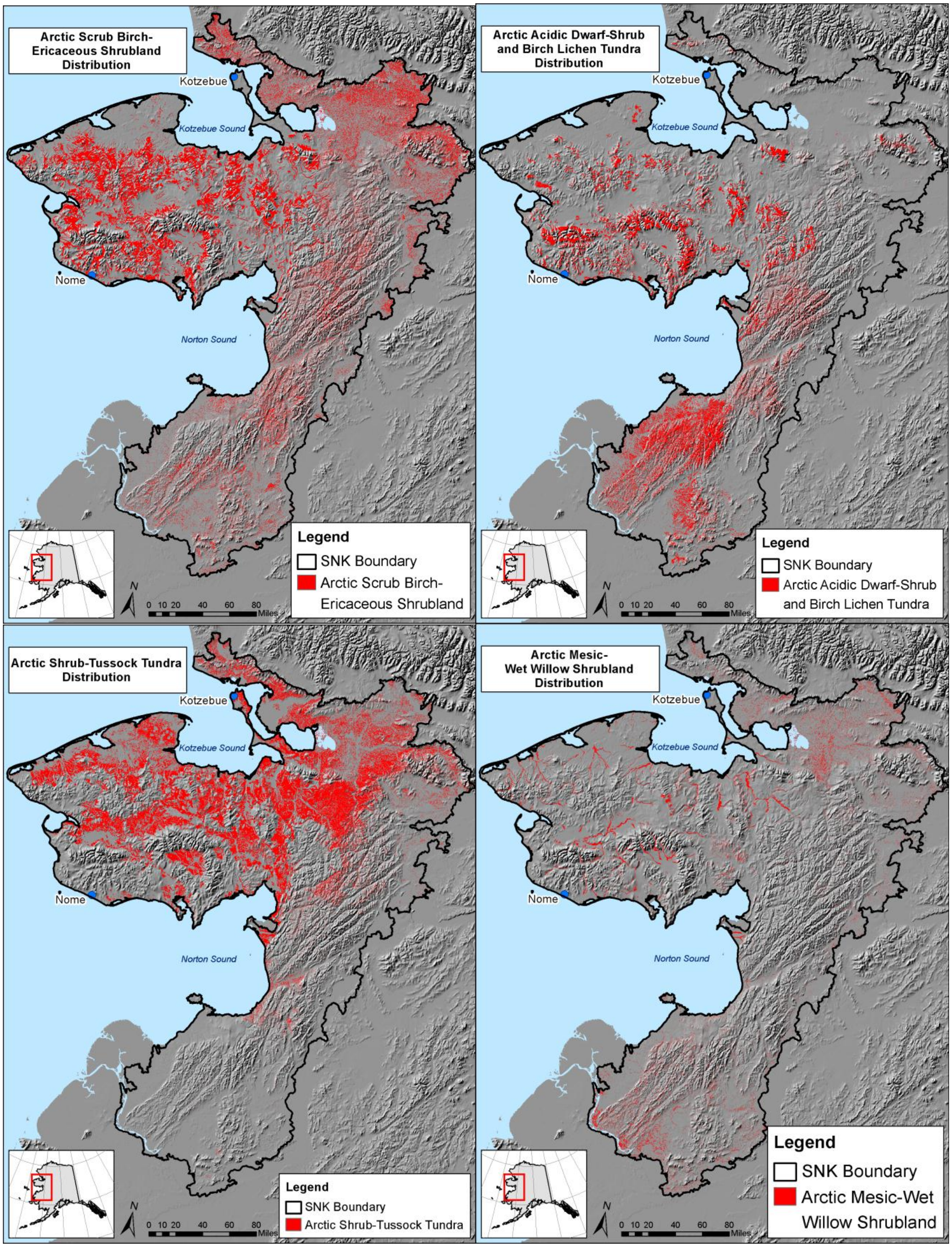


Table 4-2. Total acreage of each terrestrial coarse-filter ecological system and percentage of ecoregion it occupies.

Terr CE Code*	Terrestrial Ecosystem Name	Total Area (Acres)	Percent Total Area of SNK REA
Upland Types			
5277	Arctic Scrub Birch-Ericaceous Shrubland	6,118,470	16.02
9908	Boreal Black or White Spruce Forest and Woodland	5,481,040	14.35
9902	Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra	3,204,510	8.39
5328	Arctic Mesic Alder	2,464,510	6.45
5104	Arctic Dwarf Shrubland	1,907,550	5.00
4335	Boreal White or Black Spruce - Hardwood Forest	1,148,550	3.01
4162	Boreal Mesic Birch-Aspen Forest	1,145,390	3.00
4288	Boreal Spruce-Lichen Woodland	726,103	1.90
5103	Arctic Acidic Sparse Tundra	585,060	1.53
7166	Arctic Lichen Tundra	416,833	1.09
9901	Arctic Mesic Tundra	342,707	0.90
3196	Bedrock Cliff, Talus, and Block Fields	87,679	0.23
3195	Arctic Active Inland Dunes	4,044	0.01
Lowland Types			
9903	Arctic Shrub-Tussock Tundra	6,065,470	15.89
9904	Arctic Wet Sedge Tundra	2,730,690	7.15
5276	Arctic Mesic-Wet Willow Shrubland	1,274,260	3.34
9358	Arctic Dwarf Shrub-Sphagnum Peatland	1,123,460	2.94
9424	Arctic Wet Sedge-Sphagnum Peatland	578,056	1.51
9376	Boreal Black Spruce Dwarf Tree Peatland	455,662	1.19
9900	Large River Floodplain	307,651	0.81
9419	Arctic Fresh Water Marsh	140,308	0.37
Coastal Types			
9414	Arctic Coastal Brackish and Tidal Marsh	217,717	0.57
7167	Arctic Marine Beach and Beach Meadow	18,711	0.05
Other or Unknown Classes			
9905	Freshwater	1,358,430	3.56
9906	Salt water	55,843	0.15
9907	Urban	1,152	0.00
9999	Unclassified	214,270	0.56
	Total	**38,183,327**	**100.00**

*The map codes are included for additional reference. The terrestrial coarse-filter CE map codes are NatureServe ecological system (ESLF) codes; some classes are mosaics, unique to this project, and do not exist in the NS ESLF classification, and therefore were assigned new unique numeric codes in the 9900 range for this assessment effort.

Figure 4-3. Examples of individual distributions for terrestrial coarse-filter CEs (two upland and two lowland types). Upper left: Arctic Scrub Birch Ericaceous Shrubland (upland); upper right: Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra (upland); lower left: Arctic Shrub-Tussock Tundra (lowland); lower right: Arctic Mesic-Wet Willow Shrubland (lowland).



Distributions of aquatic CEs were mapped using a variety of data sets and methods. The distribution of two coarse-filter CEs, Large, Connected Lakes and Headwater Streams, and a fine-filter subsistence species, coho salmon, are shown as examples in Figure 4-4 and Figure 4-5, respectively.

Figure 4-4. Examples of individual distributions for aquatic coarse-filter CEs: Large, Connected Lakes (left) and Headwater Streams (right). The width of Headwater Streams has been enlarged for visibility.

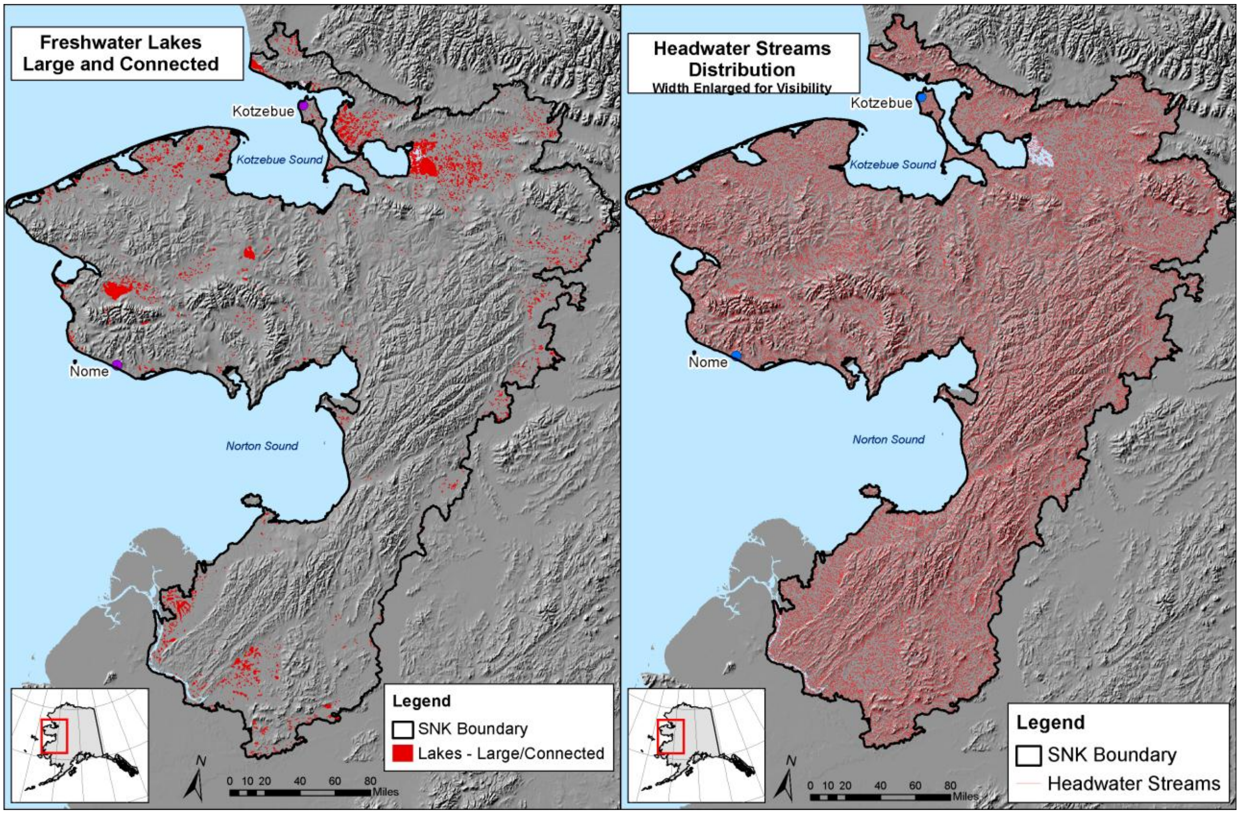
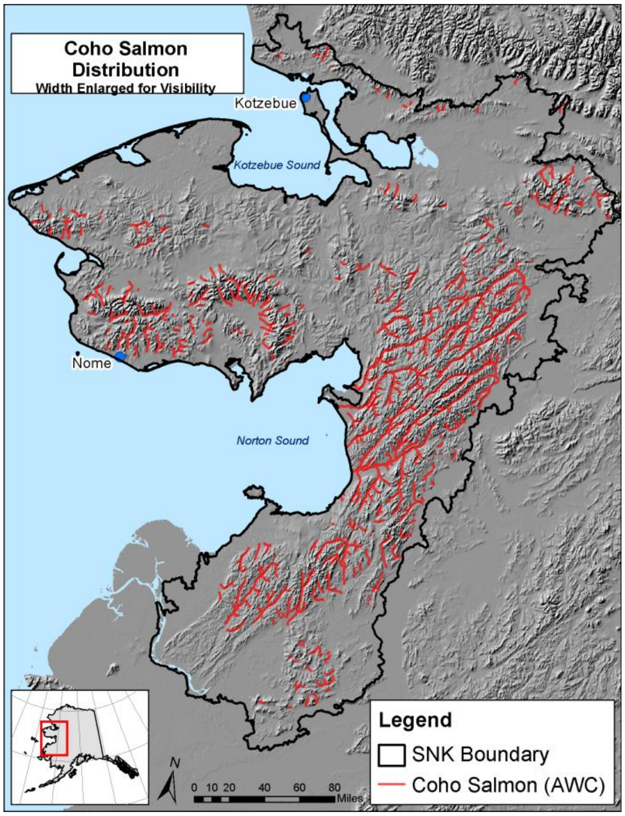
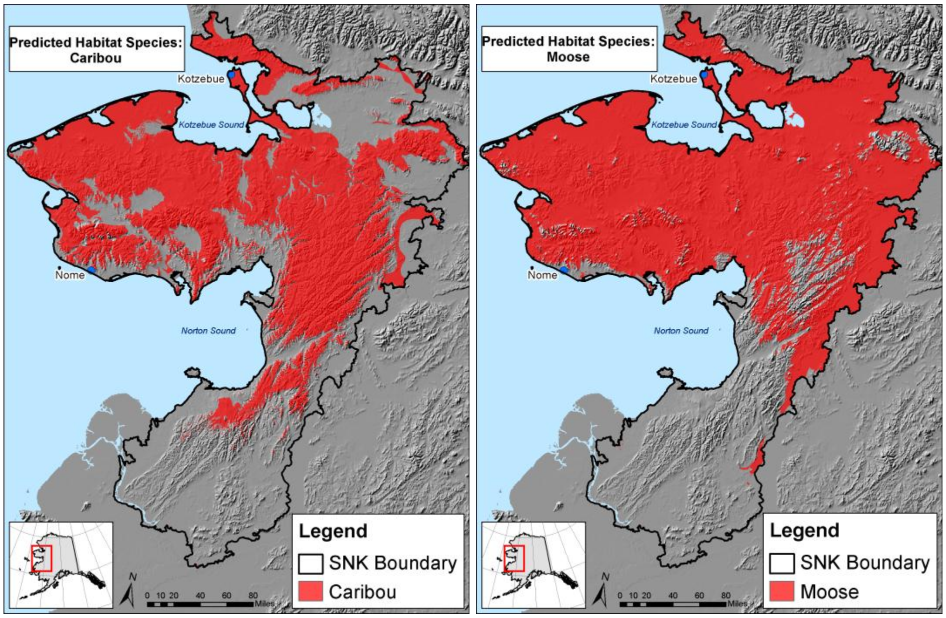


Figure 4-5. Modeled distribution of Coho salmon.



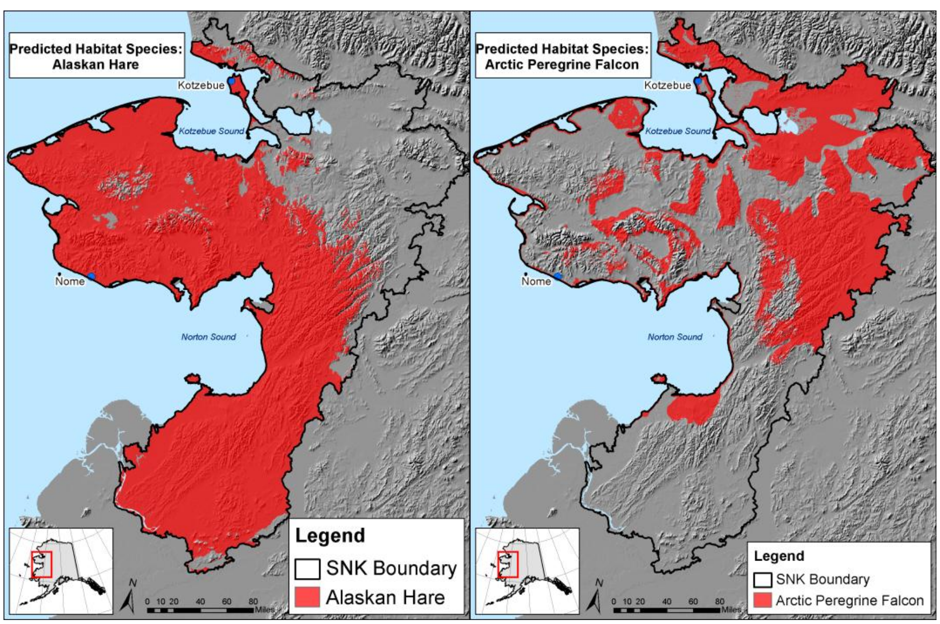
Several species are important from both a subsistence and natural resources management perspective. The draft set of predictive habitat models developed by the Alaska GAP program were used for potential distribution for terrestrial landscape species CEs, including subsistence birds and mammals. Figure 4-6 illustrates the predicted habitat for two subsistence species, caribou and moose.

Figure 4-6. Modeled potential habitat of two terrestrial subsistence species, caribou and moose.



Predicted habitat for two of the landscape species CEs, Alaskan hare and Arctic peregrine falcon, is shown in Figure 4-7.

Figure 4-7. Modeled potential habitat for two landscape species, Alaskan hare and Arctic peregrine falcon.



4.4 Current Status of Managed Lands

4.4.1 CEs and Managed Lands

88: What are the proportions of CEs that coincide with different management areas?

The relationship between conservation elements and managed and designated lands was characterized by intersecting CE distributions with the USGS Protected Areas Database (Figure 4-8). Table 4-3 provides an overall summary of the percent of the ecoregion that is in each land management/ownership class. The statistics in Table 4-4 show the percentage of each CE's extent found within various categories of land ownership/management in the ecoregion (e.g., BLM managed lands). The Bureau of Land Management manages the largest percentage of land (~42%) within the ecoregion. Consequently, the majority of many CEs' spatial extent occurs on BLM lands (columns three and four in Table 4-4), with some notable exceptions (bold values in Table 4-4). For example, over 40% of all four lake CEs occur in national wildlife refuges, and 61% of the extent of estuaries occurs on native corporation lands. The latter statistic is expected given that native communities would have been established based in part on location of traditional subsistence species and access to those species.

Figure 4-8. USGS Protected Areas Database (PADUS) v1.2 primary land management description/designation map (left) and example map of Arctic Shrub-Tussock Tundra CE distribution (black) overlaid with USGS PADUS primary land management description/designation map (right).

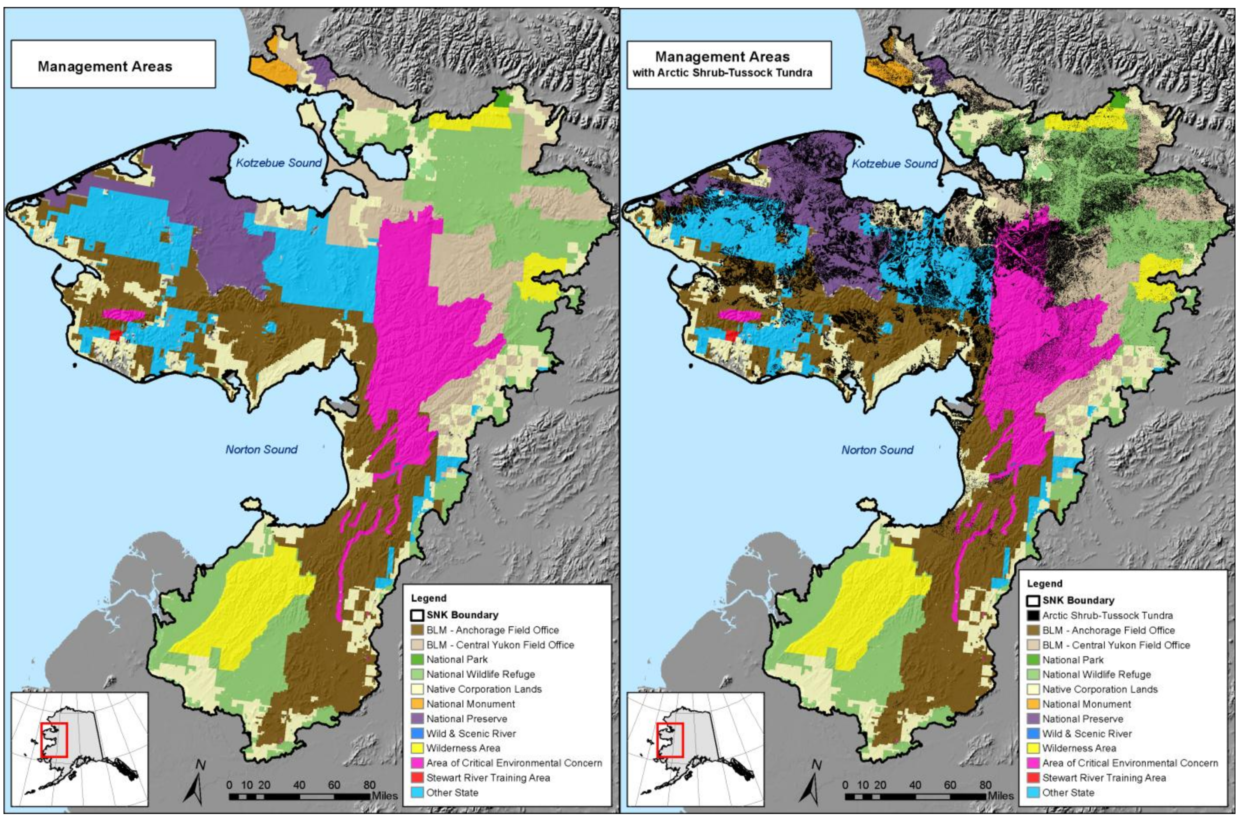


Table 4-3. Percent of the ecoregion in various land management/ownership categories.

Management Class	Percent of Ecoregion
BLM - Anchorage Field Office	21.43
BLM - Central Yukon Field Office	10.56
Area of Critical Environmental Concern	10.59
National Wildlife Refuge	17.85
Native Corporation Lands	14.58
Other State	10.89
National Preserve	7.44
Wilderness Area	5.79
National Monument	0.63
National Park	0.16
Stewart River Training Area	0.07
Wild Scenic River	0.02

Table 4-4. Percent of CE distribution within each USGS Protected Areas Database (PADUS) v1.2 primary land management description/designation class. Primary land management description/designations (columns) are ordered in the table from classes with the most extensive distributions in the ecoregion (i.e., Bureau of Land Management) to classes with the least extensive distributions (i.e., Wild & Scenic Rivers). For each CE, the cell with the largest percentage (i.e., distribution) is in bold. The mapped or modeled spatial distribution of all CEs was treated in a raster format, resulting in *acreage* totals for all CEs in the "Total Area" column (rather than, for example, stream and fish CEs being reported in miles). The key is understanding the approximate *proportion* of overlap between CEs and different categories of ownership/management.

Element Name	Total Area of CE (acres)	Bureau of Land Management - Anchorage	Bureau of Land Management - Central Yukon	Area of Critical Environmental Concern	National Wildlife Refuge	Native Corporation Lands	Other State	National Preserve	Wilderness Area	National Monument	National Park	Stewart River Training Area	Wild & Scenic River
Aquatic Coarse Filter													
Headwater Streams	1,276,132	**22%**	11%	10%	19%	15%	10%	7%	6%	1%	0%	0%	0%
Low-gradient Streams	367,340	19%	7%	8%	**24%**	19%	9%	8%	5%	1%	0%	0%	0%
Rivers	91,127	**22%**	14%	19%	9%	10%	11%	6%	8%	0%	0%	0%	0%
Estuaries	15,915	5%	6%	0%	6%	**61%**	4%	15%	0%	3%	0%	0%	0%
Lakes – Large, Connected	611,179	12%	3%	0%	**43%**	21%	1%	15%	2%	3%	0%	0%	0%
Lakes – Large, Disconnected	118,861	6%	4%	0%	**48%**	30%	1%	8%	1%	1%	0%	0%	0%
Lakes – Small, Connected	77,755	10%	7%	2%	**42%**	20%	4%	13%	2%	1%	0%	0%	0%
Lakes – Small, Disconnected	270,525	9%	5%	1%	**42%**	29%	3%	9%	2%	1%	0%	0%	0%
Hot Springs	2	22%	**33%**	0%	11%	11%	11%	11%	0%	0%	0%	0%	0%
Aquatic Fine Filter													
Alaska Blackfish	405,332	10%	5%	1%	**38%**	28%	3%	13%	1%	1%	1%	0%	0%
Chinook Salmon	88,155	24%	5%	15%	16%	**28%**	2%	0%	9%	0%	0%	0%	0%
Chum Salmon	86,864	25%	4%	10%	17%	**32%**	6%	1%	4%	0%	0%	0%	0%
Coho Salmon	72,637	26%	11%	**29%**	7%	11%	7%	1%	8%	0%	0%	0%	0%
Dolly Varden	607,419	**27%**	14%	22%	7%	8%	9%	5%	8%	0%	0%	0%	0%
Pink Salmon	55,783	24%	1%	7%	12%	**43%**	7%	2%	5%	0%	0%	0%	0%
Sheefish	26,056	2%	2%	1%	40%	**51%**	1%	0%	1%	0%	1%	0%	0%
Sockeye Salmon	17,431	9%	3%	8%	22%	**48%**	10%	0%	0%	0%	0%	0%	0%
Terrestrial Coarse Filter - Ecological Systems													
Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra	3,183,136	**32%**	4%	12%	13%	7%	11%	4%	17%	0%	0%	0%	0%
Arctic Acidic Sparse Tundra	568,923	24%	0%	7%	0%	22%	**42%**	4%	0%	0%	0%	0%	0%
Arctic Active Inland Dunes	4,044	0%	0%	0%	0%	0%	0%	0%	**98%**	0%	2%	0%	0%
Arctic Coastal Brackish and Tidal Marsh	216,766	9%	4%	0%	9%	**68%**	2%	6%	0%	1%	0%	0%	0%
Arctic Dwarf-Shrubland	1,873,633	**29%**	7%	18%	10%	12%	12%	4%	6%	2%	0%	0%	0%
Arctic Dwarf-Shrub-Sphagnum Peatland	1,121,717	7%	5%	0%	**61%**	19%	1%	3%	3%	1%	0%	0%	0%

Element Name	Total Area of CE (acres)	Bureau of Land Management - Anchorage	Bureau of Land Management - Central Yukon	Area of Critical Environmental Concern	National Wildlife Refuge	Native Corporation Lands	Other State	National Preserve	Wilderness Area	National Monument	National Park	Stewart River Training Area	Wild & Scenic River
Arctic Mesic Alder	2,455,966	**31%**	10%	10%	10%	11%	5%	2%	21%	0%	0%	0%	0%
Arctic Mesic-Wet Willow Shrubland	1,261,850	16%	6%	3%	**28%**	21%	9%	7%	9%	0%	1%	0%	0%
Arctic Scrub Birch-Ericaceous Shrubland	6,041,350	18%	11%	9%	16%	12%	**21%**	7%	4%	1%	0%	0%	0%
Arctic Shrub-Tussock Tundra	6,025,008	15%	**18%**	10%	16%	8%	17%	15%	0%	1%	0%	0%	0%
Arctic Wet Sedge Tundra	2,688,252	19%	8%	4%	14%	**21%**	16%	16%	1%	1%	0%	0%	0%
Boreal Black or White Spruce Forest and Woodland	5,472,382	**28%**	13%	20%	17%	13%	3%	0%	6%	0%	0%	0%	0%
Boreal Mesic Birch-Aspen Forest	1,142,698	**25%**	18%	10%	21%	19%	2%	0%	3%	0%	0%	0%	0%
Boreal White or Black Spruce - Hardwood Forest	1,146,740	**30%**	11%	5%	20%	23%	5%	0%	5%	0%	0%	0%	0%
Large River Floodplain	307,277	1%	1%	2%	**48%**	40%	3%	0%	6%	0%	0%	0%	0%
Local Species													
Arctic Char	451	0%	0%	**100%**	0%	0%	0%	0%	0%	0%	0%	0%	0%
Emperor Goose	1,512,110	**29%**	1%	0%	2%	28%	18%	22%	0%	0%	0%	0%	0%
Hudsonian Godwit	25,093,501	**21%**	12%	12%	20%	13%	8%	6%	8%	1%	0%	0%	0%
Kittlitz's Murrelet	5,968,019	**38%**	1%	1%	0%	16%	30%	11%	0%	2%	0%	0%	0%
McKay's Bunting	12,082,313	**37%**	3%	10%	10%	19%	8%	0%	12%	0%	0%	0%	0%
Red Knot	6,341,049	**34%**	2%	6%	0%	23%	28%	7%	0%	1%	0%	0%	0%
Spectacled Eider	11,479,970	19%	11%	1%	8%	**22%**	18%	18%	1%	2%	0%	0%	0%
Terrestrial Landscape Species - Mammals													
Alaskan Hare	25,688,098	**31%**	4%	11%	9%	14%	14%	10%	6%	1%	0%	0%	0%
Beaver	34,224,063	**23%**	11%	12%	18%	14%	11%	4%	6%	1%	0%	0%	0%
Black Bear	15,639,312	**23%**	14%	18%	21%	13%	4%	0%	7%	0%	0%	0%	0%
Brown Bear	28,205,920	**21%**	13%	14%	15%	13%	12%	6%	6%	1%	0%	0%	0%
Moose	25,483,759	15%	13%	11%	**17%**	14%	16%	11%	2%	1%	0%	0%	0%
Muskox	19,432,908	**21%**	11%	15%	11%	8%	20%	13%	2%	1%	0%	0%	0%
Western Arctic Caribou	19,780,264	17%	17%	**18%**	7%	9%	17%	13%	2%	1%	0%	0%	0%
Terrestrial Landscape Species - Birds													
Arctic Peregrine Falcon	14,170,464	8%	21%	17%	**22%**	14%	7%	5%	4%	1%	0%	0%	0%
Bar-tailed Godwit	24,226,496	**26%**	6%	12%	10%	15%	15%	7%	7%	1%	0%	0%	0%
Black Scoter	21,191,119	18%	8%	3%	**26%**	20%	10%	9%	5%	1%	0%	0%	0%
Bristle-thighed Curlew	15,537,751	**27%**	1%	7%	9%	13%	19%	14%	10%	0%	0%	0%	0%
Cackling Goose	9,990,995	14%	8%	3%	**33%**	25%	3%	9%	3%	1%	1%	0%	0%
Common Eider	3,573,260	12%	11%	0%	6%	26%	6%	**35%**	0%	4%	0%	0%	0%
King Eider	11,385,722	26%	2%	4%	0%	16%	**29%**	23%	0%	0%	0%	0%	0%

Element Name	Total Area of CE (acres)	Bureau of Land Management - Anchorage	Bureau of Land Management - Central Yukon	Area of Critical Environmental Concern	National Wildlife Refuge	Native Corporation Lands	Other State	National Preserve	Wilderness Area	National Monument	National Park	Stewart River Training Area	Wild & Scenic River
Yellow-billed Loon	4,603,796	9%	18%	1%	3%	15%	15%	**37%**	0%	3%	0%	0%	0%
Species Assemblages													
Marine mammal haul-out sites and concentration areas	37,889	11%	5%	0%	9%	**50%**	9%	16%	0%	1%	0%	0%	0%
Seabird Colonies	361,908	19%	4%	0%	3%	**48%**	7%	9%	0%	10%	0%	0%	0%
Waterfowl concentration areas	10,321,473	11%	6%	2%	**35%**	23%	4%	14%	3%	1%	0%	0%	0%
Reindeer													
Reindeer Grazing Allotments	13,751,193	**29%**	6%	1%	0%	16%	28%	20%	0%	0%	0%	0%	0%
Caribou Habitat Ranges													
WAH caribou migratory range	3,076,610	0%	21%	0%	**39%**	21%	1%	4%	8%	6%	0%	0%	0%
WAH caribou winter range	14,140,318	21%	15%	**26%**	11%	7%	13%	7%	0%	0%	0%	0%	0%

4.5 Change Agent Distribution and Intensity

4.5.1 Climate Change

4.5.1.1 Climate Trends: Temperature and Precipitation

The information in this section, such as the baseline climate against which future projections are compared, forms the foundation for addressing the management question highlighted here. This question is directly addressed in the Future Conditions chapter.

What are the potential future climate scenarios for temperature and precipitation?

Between 1949 and 1998, annual and seasonal mean temperature increases were found throughout the state of Alaska, with the majority of climate stations showing changes that are statistically significant at the 95% level or better. In the Seward Peninsula region, annual temperature increased by approximately 1.5°C during this time period, although winter temperatures increased by more than 2°C (Stafford et al. 2000). Trends in precipitation are less clear, due to higher variability in precipitation data.

During the historical time period used as a benchmark by this project (1901-1980), temperatures during the coldest month of the year (January) averaged between -9 and -21°C across the region (Figure 4-9), with the warmest areas being along the coastlines, and the coldest areas being in the northeastern inland regions of the study area. During the hottest month of the year (July) this pattern is largely reversed, with the moderating effects of the ocean keeping coastal areas cooler, and inland areas having the highest mean temperatures. Across the study area, the historical mean temperature range for July is 7-17°C. Thus, regions with very similar mean annual temperatures – and very similar soil temperatures and permafrost conditions – may in fact have extremely different climates, from the point of view of seasonality, climate extremes, and supported vegetation and wildlife.

Mean values for historical precipitation show similar regional patterns in both summer and winter (Figure 4-10), with the highest precipitation occurring in the highest elevation areas, and relatively low precipitation along the coastlines, particularly around Kotzebue Sound. For further detail on mean temperature and precipitation, including tables summarized by month and by ecoregion, see Appendix A.

Both temperature and precipitation varied considerably from year to year across the 80-year historical reference period. As will be discussed later, this natural variability must be taken into account when considering ongoing and future climate trends.

It is clear that climate change impacts are already underway in the SNK ecoregion. Reconstructions of vegetation change attributable to past warming show that spruce trees have been encroaching into tundra since the 1880s, converting a 10-km band of shrub tundra to low-density forest-tundra (Lloyd et al. 2002). Remote sensing research implies that the greening effects attributable to warming are less pronounced on the Seward Peninsula than in the northern Arctic (Stow et al. 2007). However, change is nonetheless occurring.

Because current climate conditions on the Seward Peninsula and surrounding regions are conducive to transitional vegetation (from tundra to boreal forest), ecotones in this ecoregion may be particularly sensitive to changes in climate. Recent research shows that ongoing change in the REA area is toward increased shrubbiness (Silapaswan et al. 2001).

Figure 4-9. Historical mean temperatures for 1901-1980 for January (left) and July (right).

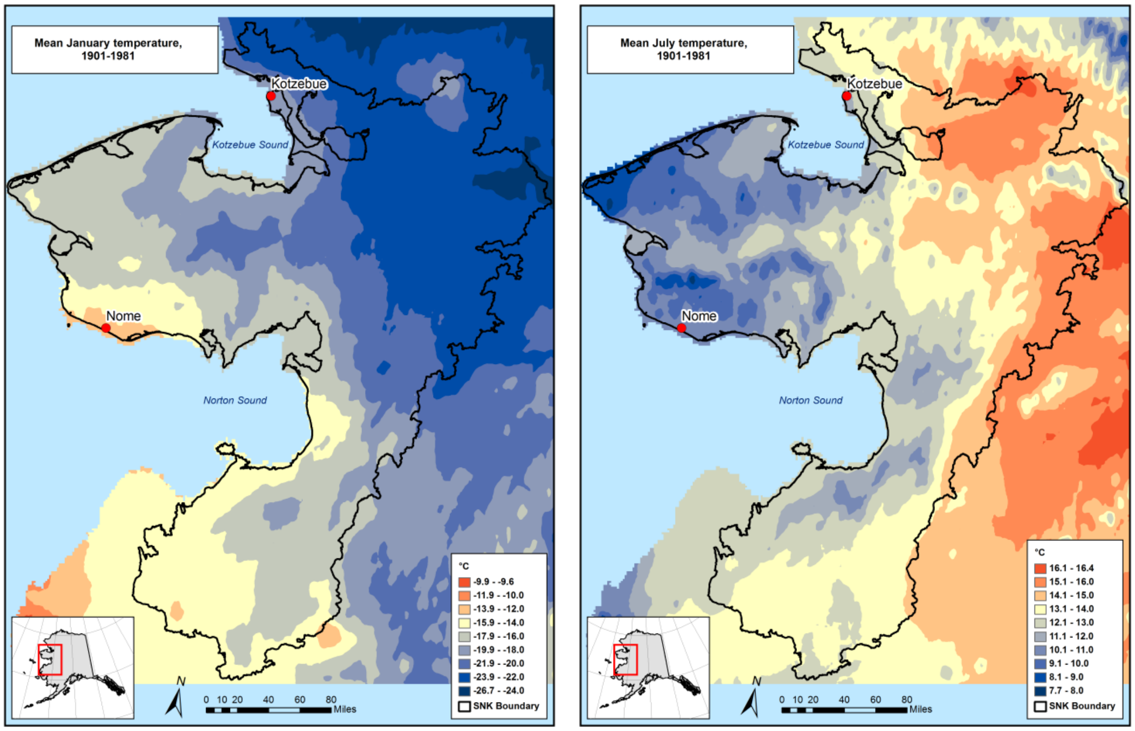
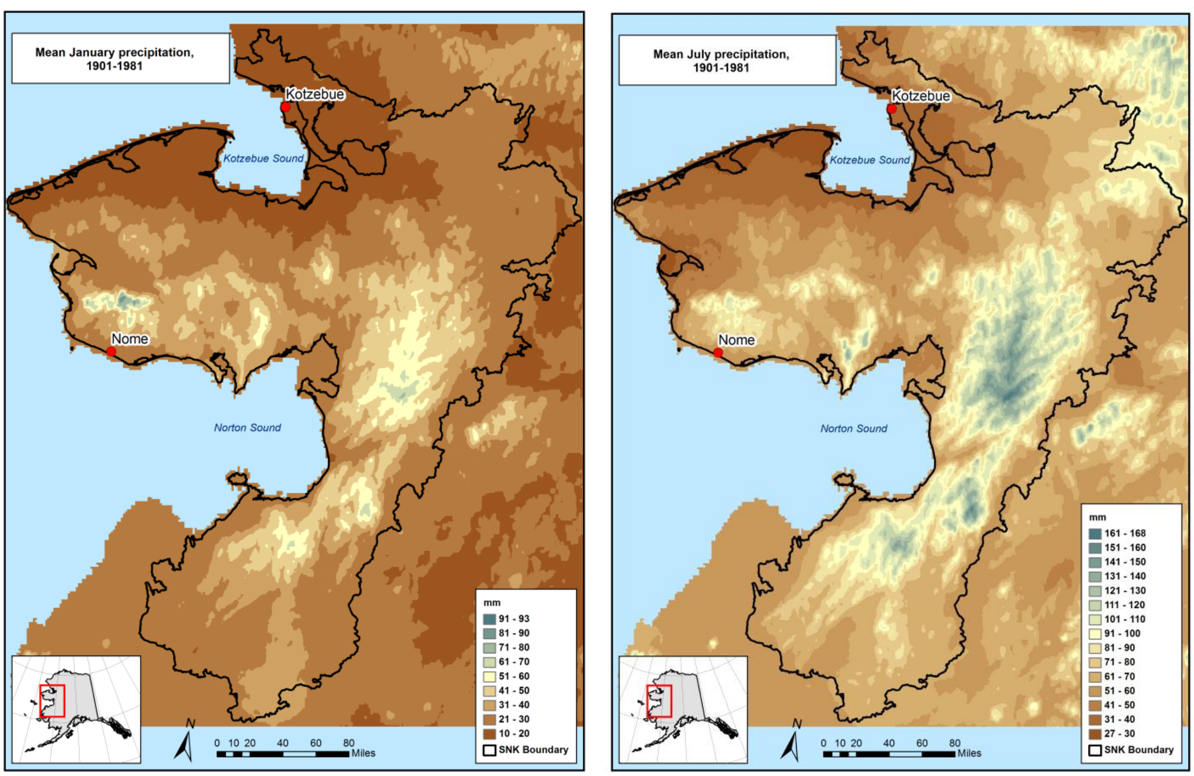


Figure 4-10. Mean total monthly precipitation (rain equivalent) for 1901-1980, for January (left) and July (right).



4.5.1.2 Permafrost

This section addresses the management question on permafrost highlighted here. This two-part question is addressed in two different parts of this report; the portion displayed in gray text, relating to future permafrost dynamics, is addressed in the **Permafrost** section of the Future Conditions chapter.

> **156**: What are the current soil thermal regime dynamics and how are these predicted to change in the future?

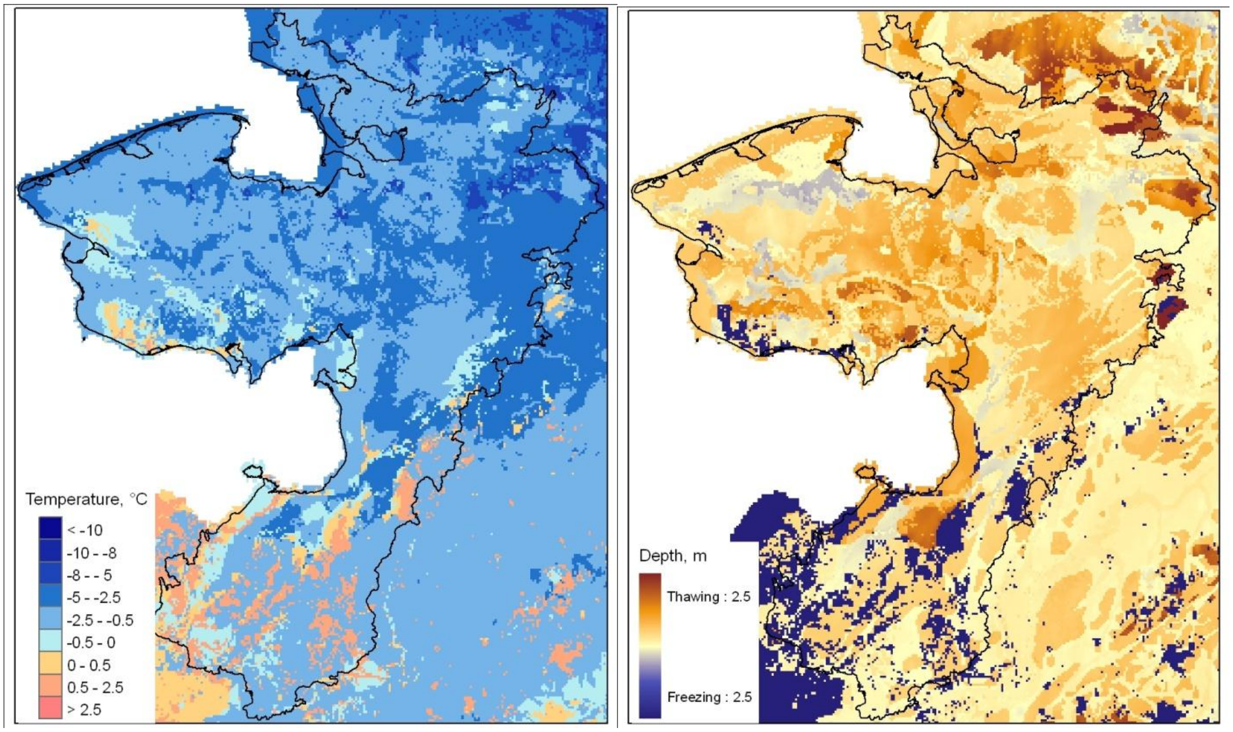
Permafrost thaw is both a result of climate change, and a change agent in its own right. For example, in lowland sites, trees began establishing in recent thermokarst areas of the tundra in the early 1900s (Lloyd et al. 2002).

Current permafrost conditions vary across the study area (Figure 4-11), with some areas of continuous permafrost to the north, and mostly discontinuous permafrost to the south. Even in areas with mean annual ground temperature (MAGT) at one meter depth well below freezing, some microsites are permafrost free. Likewise, even in the warmest areas, permafrost may underlie cold microsites. While MAGT is primarily dependent on mean annual temperature, the active layer thickness (ALT) is dependent on seasonal climate and surface conditions, with deeper thawing taking place in areas with either hot summer temperatures, little surface shading and insulation, or both, and deeper winter freezing taking place in areas with colder winter temperatures or lesser insulation due to minimal snow cover.

In permafrost areas, the formation and drainage of thermokarst lakes plays a key role in the hydrologic dynamics of the ecosystem. Permafrost thaw leads to multiple effects, including frost heaves, pits, gullies, differential tussock growth, localized drying, and changes in shrub and moss species abundance, productivity, and mortality (Osterkamp et al. 2009). Permafrost degradation can occur in many different ways, depending on slope, soil texture, hydrology, and ice content, and each of these modes has different effects on ecosystems, human activities, infrastructure, and energy fluxes (Jorgenson and Osterkamp 2005).

Permafrost in the SNK ecoregion is already undergoing change. Remote sensing imagery shows that in recent decades, the total (combined) surface area of all lakes has decreased (Riordan et al. 2006), although the number of lakes has increased, a phenomenon caused by the formation of remnant ponds following partial drainage of larger water bodies. Research also shows that lake drainage in this region is triggered by lateral breaching rather than subterranean leaching (Jones et al. 2011). These hydrologic changes may impact community water supplies (Chambers et al. 2007), especially given large increases in per capita freshwater use since the 1970s (Alessa et al. 2008).

Figure 4-11. Mean Annual Ground Temperature at one meter depth (left) and Active Layer Thickness (right) in 2011, as estimated by the GIPL permafrost model.



4.5.1.3 Bioclimatic Envelopes: Conservation Elements

63: Where will the distribution of CEs and wildlife ranges likely experience significant change in climate?

In order to predict how climate change may shift the suitable climatic conditions for a species or vegetation class, first its current climatic niche – or "bioclimate envelope" – is defined by correlating its current range/localities with current climatic conditions. The species' identified climate niche can then be projected into the future using downscaled Global Circulation Models (GCMs) to predict where the climate niche or envelope will occur at different time slices in 21st century climate scenarios. This information offers one basic building block for a myriad of biogeographical studies that include prediction of extirpation risk, analysis of future conservation priorities, and species range shifts. The current bioclimate envelopes are the foundation for developing future bioclimate envelopes and are presented here for reference; management question 63 is addressed by the future bioclimate envelopes, which are presented and discussed in the corresponding section of the Future Conditions chapter.

Bioclimatic envelope models were generated using the CRU 2km resolution (1901-1981) monthly data to define the current climate niche of a species (Figure 4-12 through Figure 4-15). If species input data was representative of a specific time frame, then the baseline was altered to match those years. For the caribou, the baseline used was 1991-2009 because the caribou range/locality dataset was from 1999-2005 (see the Bioclimate Envelope section in Appendix B). It is important to keep in mind that the current bioclimate envelope of a species is defined by the input locality data and can be affected by inaccuracies in the data such as sample selection bias or an incomplete dataset. The maps below (Figure 4-12 through Figure 4-15) depict the available locality data for each modeled species; as noted in the

Methods chapter, the locality data were provided by the AK GAP program and were used to develop models of species' predicted habitat, which were used as species CE distributions in this REA.

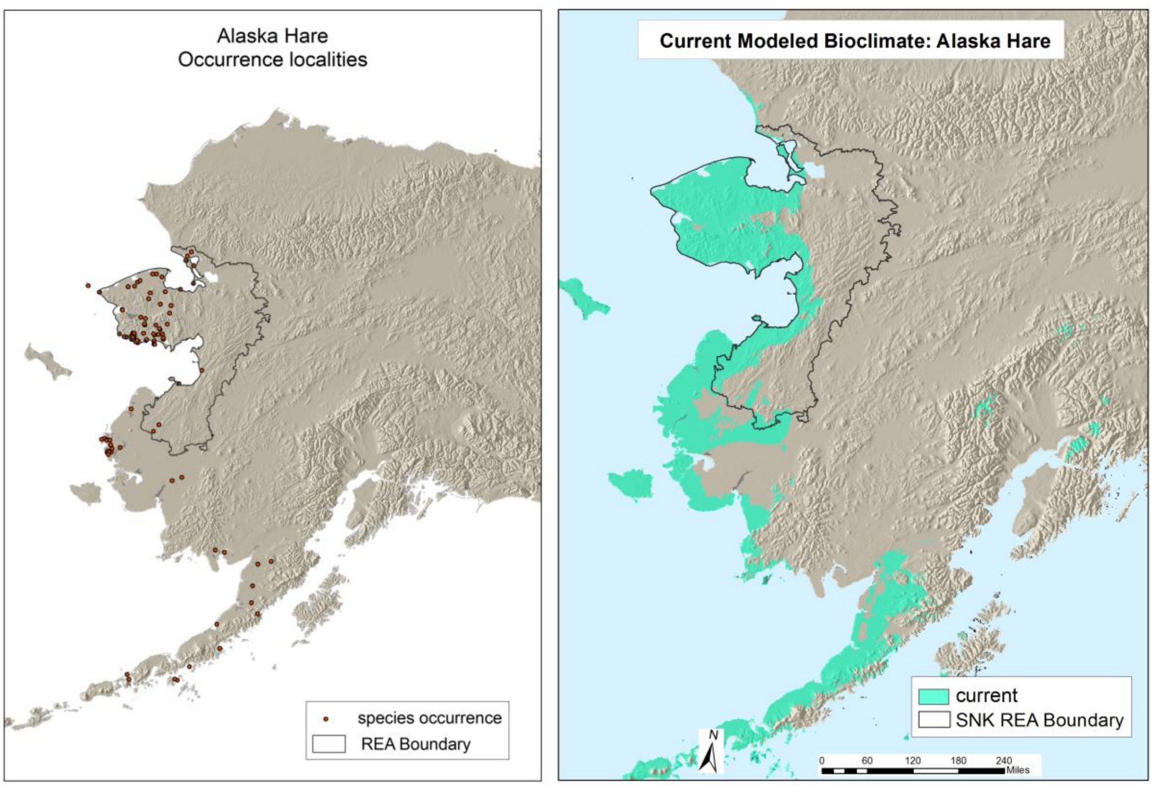
Table 4-5 aims to answer the question: which climate variables matter most for the species in question? The table shows the top three variables that contributed to training the current Maxent model for each species. "Temp" is average temperature and "precip" is total precipitation. The number next to the variable stands for the corresponding month. For example, March average temperature (temp3) contributed to 55% of model fitting for the winter range of the Western Arctic Caribou Herd. Knowing variable contributions for species might help to understand how a species might be vulnerable to climate change and where to focus attention for future research.

Table 4-5. Variable contribution in Maxent model training for modeled current bioclimatic envelopes.

CE/CA	Species	Top 3 variable contribution	AUC
Mammal	Alaskan hare	temp11 31%, precip6 15%, temp4 13%	.961
Birds	Arctic Peregrine Falcon	precip7 33%, precip6 32%, temp6 14%	.966
	Bar-Tailed Godwit	precip6 74%, precip7 11%, precip8 8%	.918
	Bristle-Thighed Curlew	precip6 62%, temp6 29%, precip7 8%	.920
	Hudsonian Godwit	temp8 40%, precip8 27%, precip6 16%	.965
Subsistence	WAH Caribou: Winter Range	temp3 55%, temp4 16%, temp1 6%	.638
Invasive CAs	Orange Hawkweed	temp4 40%, temp3 14%, temp5 8%	.953
	White Sweetclover	precip4 27%, temp5 20%, temp8 19%	.972

4.5.1.3.1 Mammals

Figure 4-12. Input localities (left) and modeled current bioclimate (right) for Alaskan hare.



4.5.1.3.2 Birds

Figure 4-13. Input localities (left) and modeled current bioclimate (right) for Arctic peregrine falcon (top) and bar-tailed godwit (bottom) breeding range.

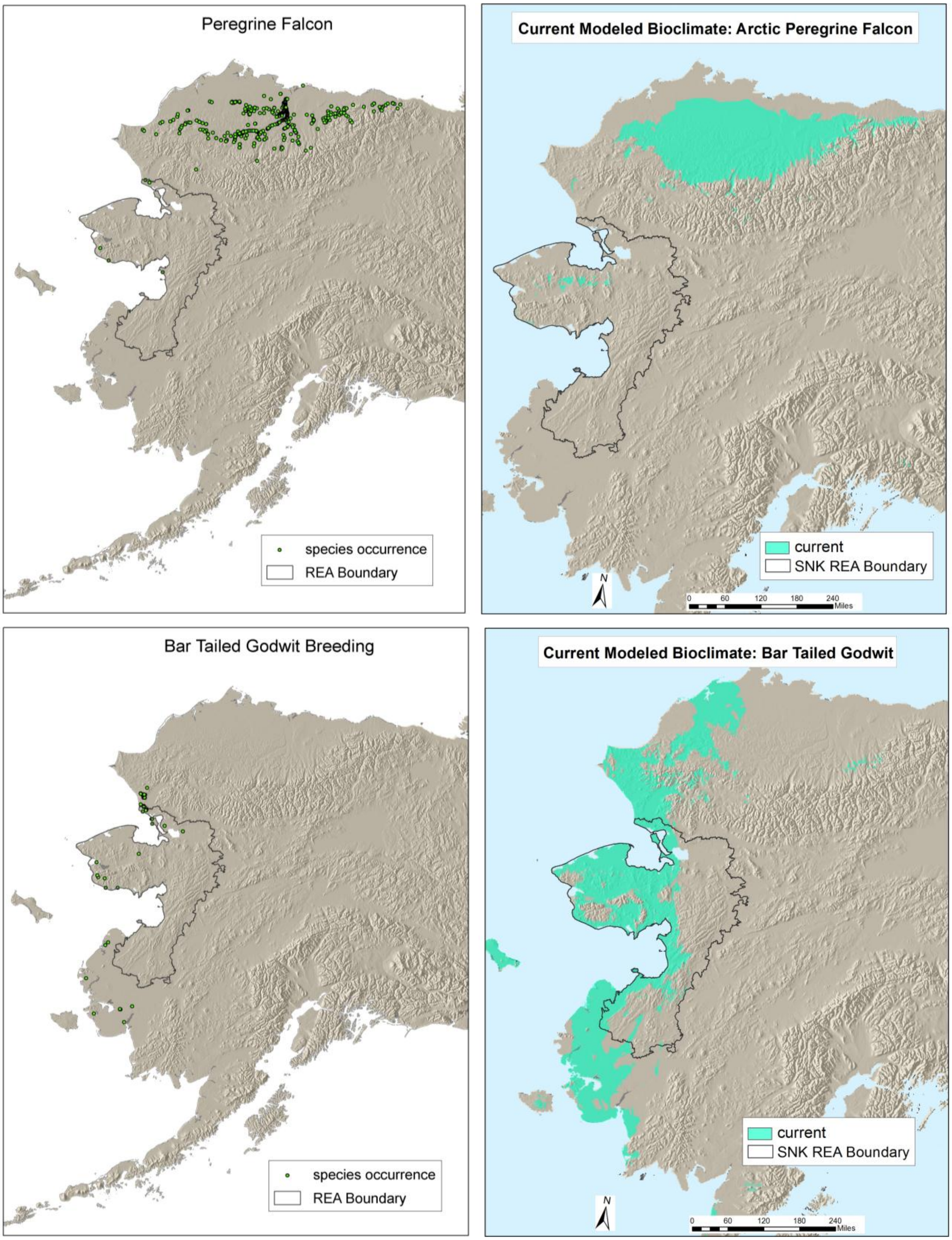
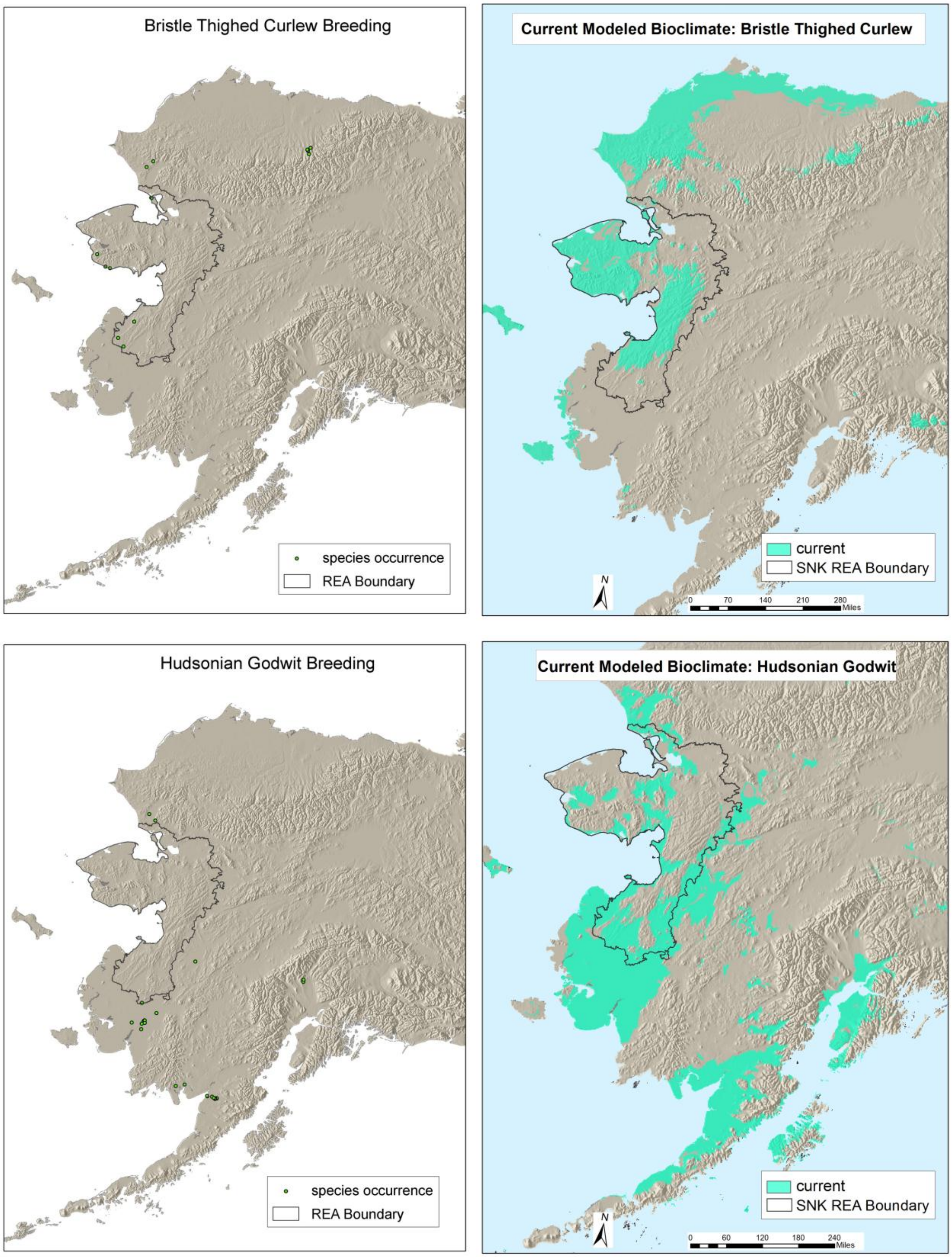
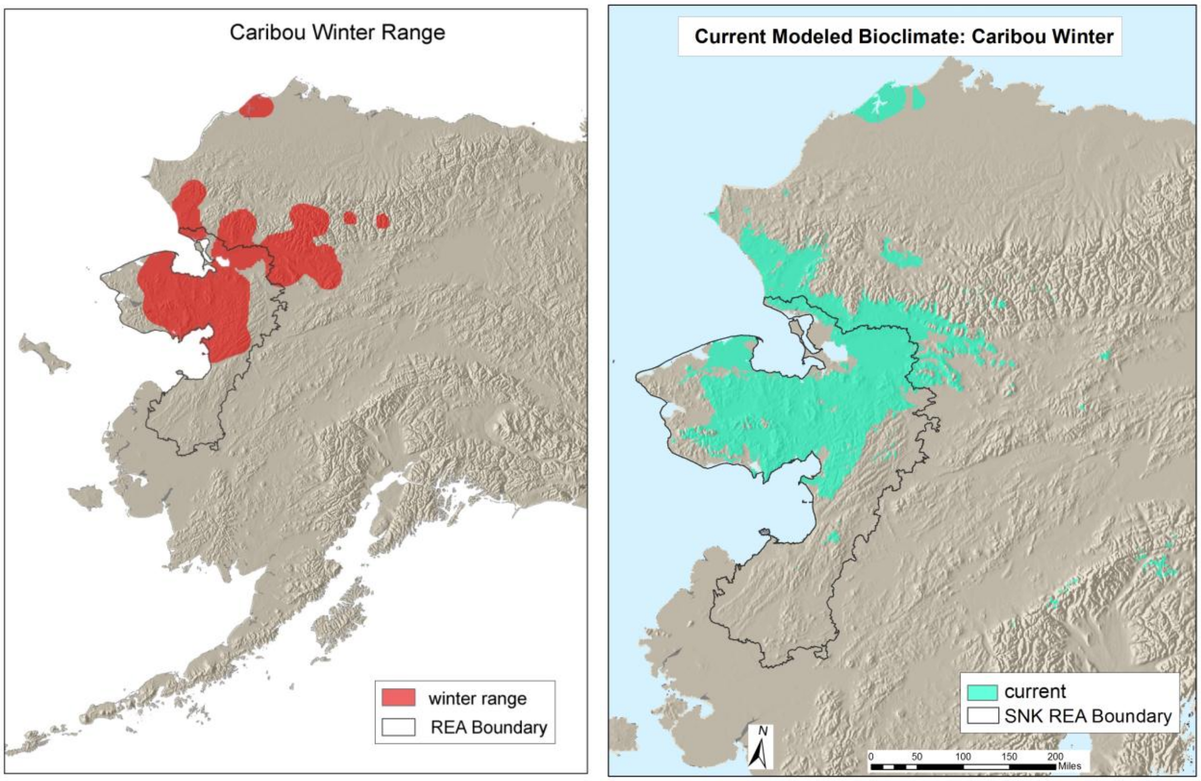


Figure 4-14. Input localities (left) and modeled current bioclimate (right) for bristle-thighed curlew (top) and Hudsonian godwit (bottom) breeding range.



4.5.1.3.3 Subsistence Species

Figure 4-15. Input locality (left) and modeled current bioclimate (right) for *winter range* of Western Arctic Caribou Herd.



4.5.2 Fire

This section addresses the first part of the multi-part management question on fire highlighted here. The other parts of the question, displayed in gray text, are addressed in the **Fire** section of the Future Conditions chapter. Additional details are also included in Appendix A.

> **129**: What is the fire history of the region and what is the potential future fire regime? What are the implications for vegetation?

Fire frequency is dependent not only on the flammability of the landscape, but also on fire ignitions from lightning, meaning that a hotter, drier climate does not necessarily mean more fires (Lynch et al. 2004). Although lightning strikes are tracked by the Alaska Fire Service (http://afsmaps.blm.gov/imf/imf.jsp?site=lightning), accuracy of measurement has been inconsistent over time, meaning that no consistent trends can be found in historical data. However, in some cases, climate change appears to be positively correlated with increased cloud-to-ground lightning activity (Kochtubajda et al. 2011).

Historically, fire has been far less common in the Seward Peninsula portion of the SNK ecoregion than in the interior boreal forest, with many areas remaining unburned over the past seventy years (Figure 4-16). Kasischke et al. (2002) analyzed variability in forest cover (particularly spruce cover), lightning strikes, and fire cycle length (or fire rotation) in the most fire-prone ecoregions in Alaska. Some of their results are summarized in Table 4-6. They found that fire cycles in selected ecoregions of the SNK range from 214 to 356 years, although these figures must be viewed in light of the variability within each ecoregion, with tundra fires occurring infrequently (Higuera 2008). The length of fire cycles in conifer-forested areas of each ecoregion tends to be shorter than in grasslands, shrubs, or deciduous forest, so these averages give only an overall sense of the impacts of fire historically. The majority of area burned is accounted for by a few high-fire years. Large fires have occurred, particularly in more inland areas (e.g., the Nulato Hills). For further detail and maps of historical fire scars, see Appendix A.

In tundra ecosystems, lichens are slow to regrow after fire, with lichen cover of only 3-4% 24-25 years post-fire on the Seward Peninsula (Jandt et al. 2008). Recent decades have seen marked change in Arctic tundra ecosystems due to the interplay of climate change, wildfire, and disturbance by caribou and reindeer; these interdependent changes are all implicated in the observed significant reduction of terricolous lichen ground cover and biomass (Joly et al. 2009). Fire can also lead to vegetation shift. In one study on the Seward Peninsula, it was found that shrub cover was higher on burned plots than unburned plots, and that cover of cottongrass (*Eriophorum vaginatum*) initially increased following the fire, and remained so for more than 14 years (Jandt et al. 2008).

Figure 4-16. Fire history from 1940 to the present (http://fire.ak.blm.gov/predsvcs/maps.php)

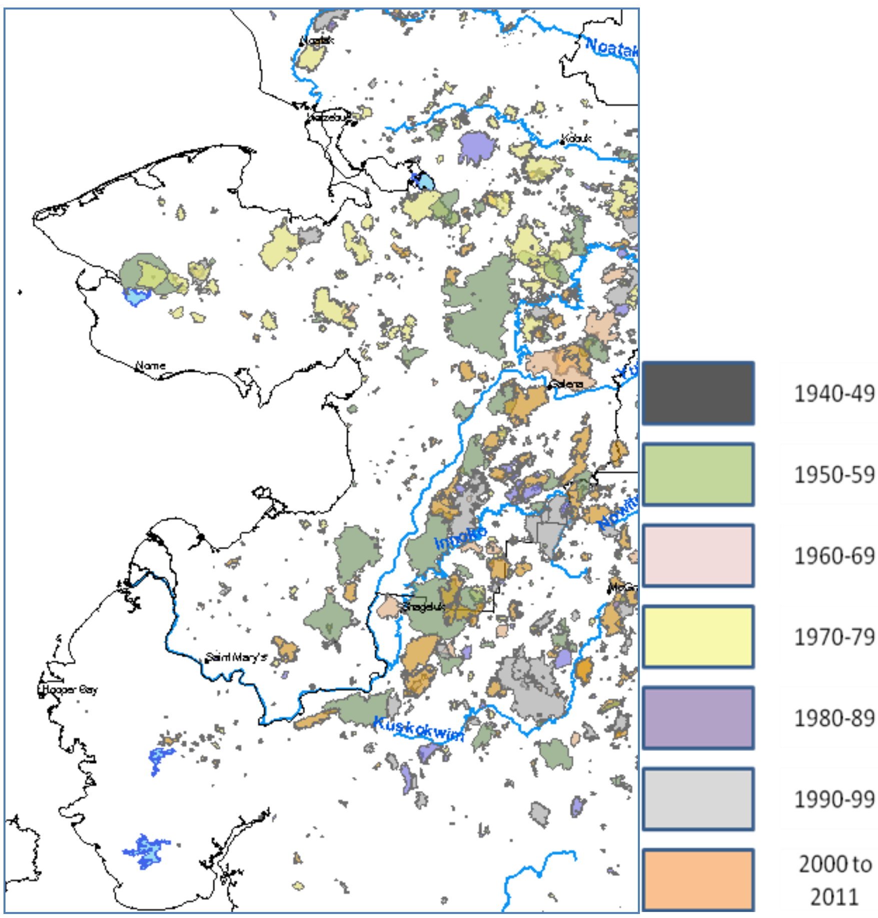


Table 4-6. Lightning frequency, percent forest cover, and estimated fire cycles by fire-susceptible ecoregion. Adapted from Kasischke et al. (2002).

	Average Lightning Strikes per 10x10 km per year	Tree cover (%)	Total conifer cover (%)	Fire return interval (years)
Nulato Hills	1.2	19	17	356
Seward Peninsula	0.3	1	1	340
Kobuk Ridges and Valleys	3	47	43	215
Tanana-Kuskokwim Lowlands	3.7	83	64	214
Yukon River Lowlands	0.3	78	55	146

4.5.3 Development

A series of management questions were identified relating to development activities and infrastructure. They generally ask the same three-part question for a variety of different development features: Where is current development? Where is planned/future development? Where do these current and planned developments overlap with CEs? This section addresses two components of this series of questions:

- Where is current development?
- Where does [current] development overlap with CEs?

The corresponding parts of this question for planned/future development – Where is planned/future development? and Where does [future] development overlap with CEs? – is addressed in the corresponding Development section in the Future Conditions chapter. Additional details on methods for assessing these management questions are provided in Appendix A.

45: Where are current and planned oil/gas activities located and where do they overlap with CEs or other relevant habitats?

46: Where are historic, current and potential mining activities located, and where do they overlap with CEs or other relevant habitat?

49: Where are current and potential recreational use areas located, and where do they overlap with CEs or other relevant habitat?

50: Where are current and planned roads located, and where do they overlap with CEs or other relevant habitat?

51: Where are historic, current and planned military sites located, and where do they overlap with CEs?

111: Where are hazardous waste sites?

4.5.3.1 Summary of Current Intensity

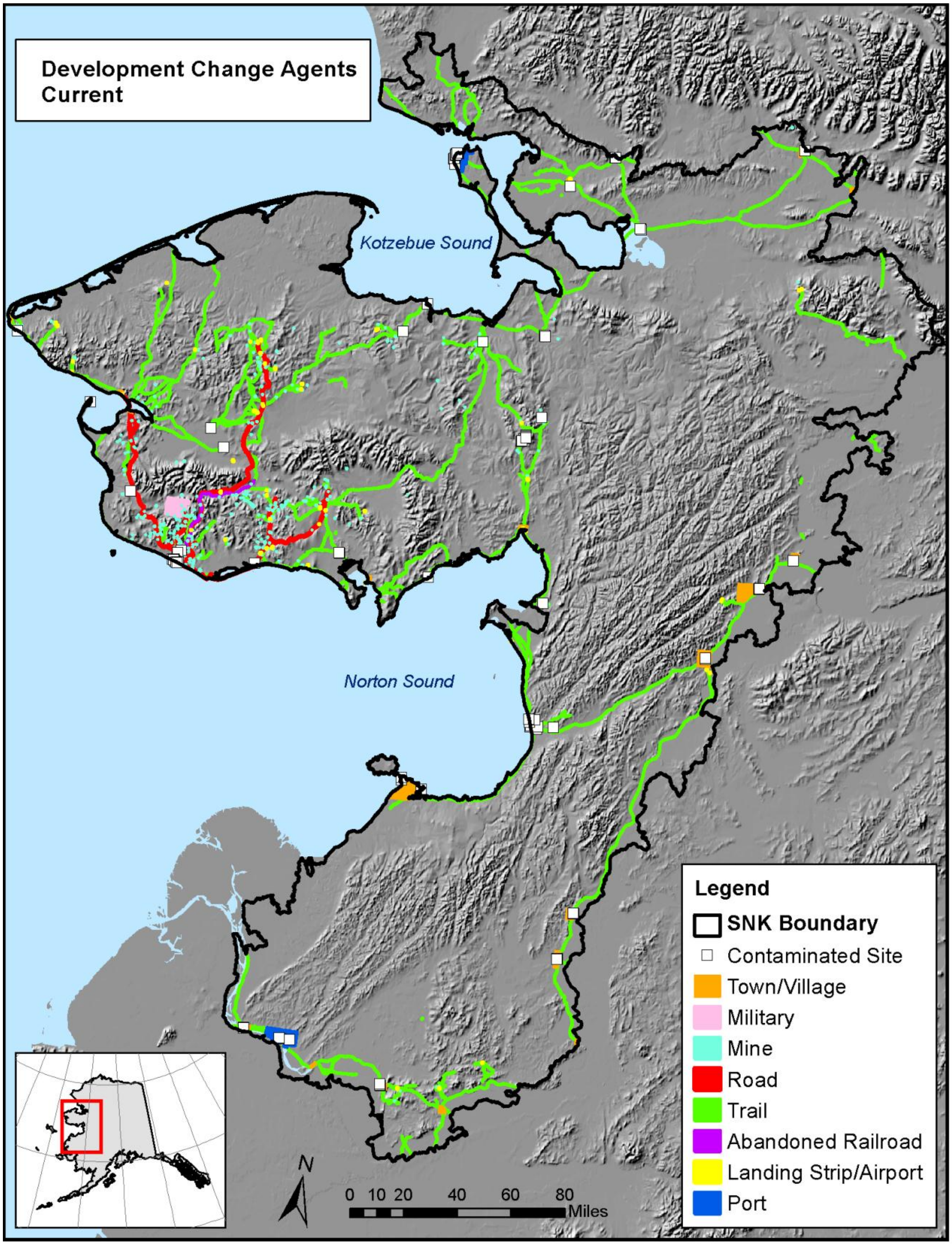
Current development is relatively limited in the SNK ecoregion, with most human populations located in smaller communities, and with primarily localized seasonal trails or ice roads used to access camps, hunting areas, and in some cases nearby communities. There are only three significant roads (gravel and not maintained in winter) outside of the communities in this ecoregion, all radiating out from Nome. Nearly all travel between communities is by small aircraft. Both Nome and Kotzebue have jet-capable airports and provide service to Anchorage, while the remainder of the ecoregion is served by numerous gravel landing strips. While 102 landing strips are specifically identified in the Alaska transportation dataset, any substantial river gravel bar is readily used as a natural landing strip. There are three small-scale, active ports in the region within the communities of Nome, Kotzebue, and St. Mary's.

Renewable energy development in this ecoregion is limited to small-scale operations to serve the power needs of Native communities. Placer mines are the primary extractive activity, but few are active; of the 380 mines in the USGS Alaska Data Resource File (ADRF), only 26 are identified as currently active. The Alaska Contaminated Sites Database identifies 121 open sites in the ecoregion. The majority of these are small, localized spills (e.g., heating oil tank leak); however, a few are more significant in terms of contaminant type and/or size. (Given the limited information documented in the database, it was not possible to consistently quantify the relative significance of these contaminated sites, nor identify their areal extent, and therefore all contaminated sites were identified as a single point/as a single 30x30 meter pixel.) There are three small-scale, active military sites in the ecoregion: Tin City Long Range Radio Relay Station, Kotzebue Long Range Radio Relay Station, and the Stewart River Training Area north of Nome. The current development footprint is illustrated in Figure 4-17. Compared to the size of the ecoregion, the footprints of these current development features or projects are relatively small. They have resulted in relatively little habitat loss, in highly localized areas.

This CA includes development features that were addressed within the following categories:

- Human population centers/communities
- Roads (gravel)
- Trails (ice roads and seasonal ATV trails)
- Railroads
- Ports
- Landing strips and airports
- Contaminated sites
- Renewable energy fund sites
- Mines
- Military

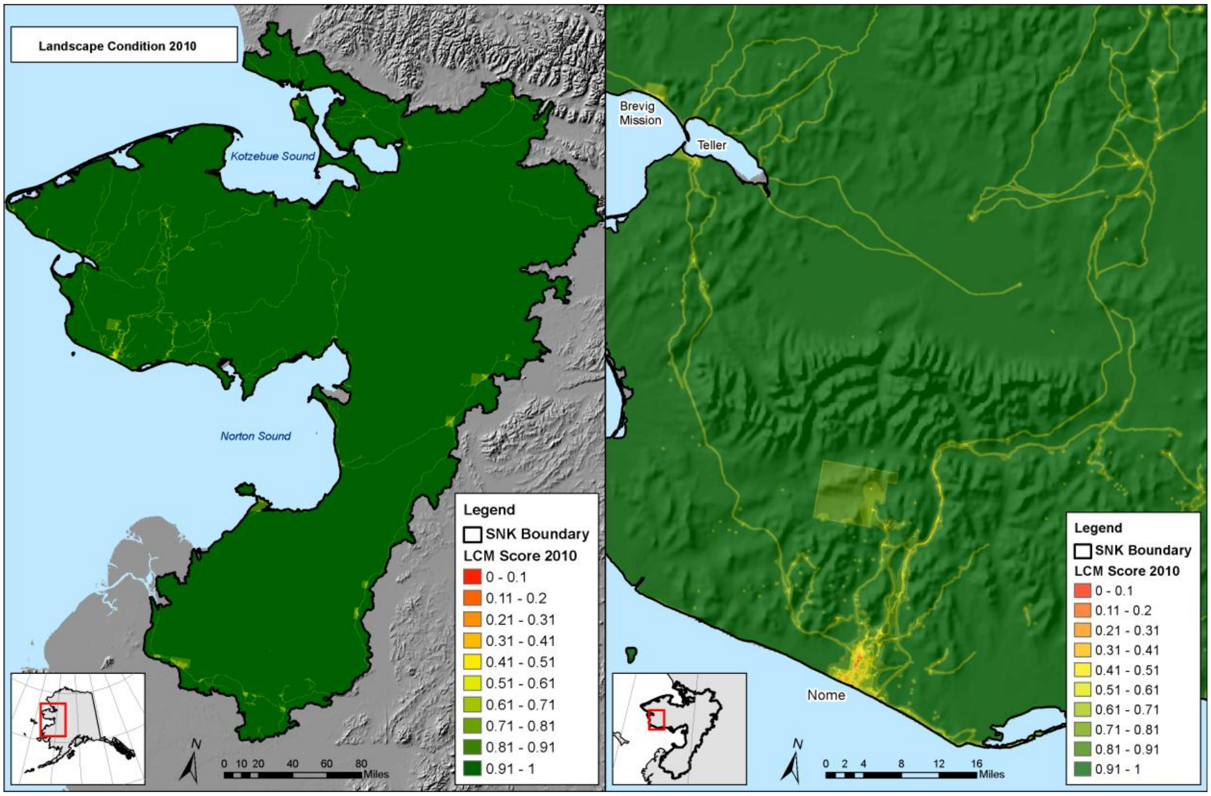
Figure 4-17. Current development in the SNK ecoregion.



4.5.3.2 Modeled Effects of Development: Landscape Condition Model

There is growing information on various kinds of stressors that impact ecosystems. Danz et al. (2007) noted that “Integrated, quantitative expressions of anthropogenic stress over large geographic regions can be valuable tools in environmental research and management.” When they take the form of a map, or spatial model, these tools initially characterize ecological conditions on the ground; from highly disturbed to apparently unaltered conditions. The landscape condition model serves as a general indicator for the ecological condition, or “viability/integrity,” of the biota and ecological systems present on a landscape. Modeled indicators such as the landscape condition index are used when comprehensive field surveys of a particular area to evaluate its condition are not feasible or not available for the area of interest. This index of landscape condition is modeled on the presence of various infrastructure features and other anthropogenic land uses or covers that may cause stress to CEs. The model goes beyond a basic anthropogenic footprint by incorporating the intensity of the impact of the footprint feature or land use (e.g., high-density urban development has a greater impact than low-density/rural development) and the distance to which the effects of the feature or land use are felt (i.e., for some features the impact extends with decreasing intensity to some distance away from that feature). Compared to many places, the SNK ecoregion is relatively unaltered, as illustrated in the landscape condition model for this ecoregion (Figure 4-18). The nature of development infrastructure in this ecoregion is assumed to have relatively low impact (compared to the type of high intensity development that is present in places like Anchorage, or in densely populated areas of the lower 48). Similarly, these features were assumed to have relatively limited distance decay effects. The primary impacts are observed around Nome, and to a lesser degree around the other Native communities. The average condition value for the ecoregion is 0.98; the highest possible condition is 1. The condition model was the primary indicator used to assess ecological status for terrestrial CEs. It was also one of the five indicators of ecological status for aquatic CEs. Appendix B contains detailed methods on how the condition model was developed.

Figure 4-18. Landscape Condition Model (LCM), 2010 (left) and zoom map of Nome area (right). The darkest green end of the color ramp indicates areas that are estimated to be least impacted, while the red end of the ramp indicates areas that are most impacted.



There are some inter-related limitations to this modeling approach. The lack of comprehensive literature quantifying the on-site and distance effects of various anthropogenic land uses on CEs necessitated the use of expert opinion to assign impact and decay scores. In addition, different CEs may experience relatively different impacts from a given land use. However, with available information and within the scope of a rapid assessment, it was not possible to develop individual condition models for each CE; the assigned impact and decay scores are general and were applied to all CEs. Finally, there are minor data limitations for the SNK; footprints for some land uses were modeled or derived using available data and simple methods and may not accurately reflect the extent of the land use. The discussion of development change agents in Appendix A summarizes these footprint accuracy issues. While there may be local inaccuracies, development is sufficiently limited in the SNK ecoregion that these inaccuracies are highly unlikely to substantially affect a CE's overall landscape condition.

4.5.4 Invasive Species

The SNK ecoregion currently has a relatively low degree of invasion by non-native species, when compared to the lower 48 or other more densely populated or heavily used regions. However, a number of non-native species have reached this region, and numerous others threaten to invade. Current and projected bioclimatic envelopes for two invasive plant species that have not yet invaded this ecoregion but are nearby were developed. These models are summarized in the Future Conditions chapter and Appendix B.

4.5.4.1 Non-Native Species

138: What is the current distribution of invasive species included as CAs?

To date, aquatic invasive species have not yet been documented in the SNK ecoregion. One non-native terrestrial animal, the Norway rat, has been documented in Nome. Throughout their global range, Norway rats are more common in cold climates and occur in northern latitudes with similar climatic zones to those found in Alaska. Although apparently limited in distribution in western Alaska, the invasiveness potential of this species in Alaska is considered extremely high (Gotthardt and Walton, 2011).

Six surveys of non-native plants have been conducted in parts of the SNK ecoregion, documenting 170 observations of 26 mildly to moderately invasive plant species (AKEPIC 2010; and see Carlson et al. 2008). (A system for ranking invasiveness of plant species was developed for Alaska by Carlson et al. 2008. The ranking system is based on ecosystem impacts, biological attributes, current distribution, available control measures, and potential for establishment based on climate. Rankings range from 0 to 100, with 100 being the most invasive.) The infestations all appear to be associated with human disturbance. The species observed are all extremely widespread throughout Alaska. Figure 4-19 illustrates the observation data and Table 4-7 lists the species found, along with their invasiveness ranking. The largest extent is 1.5 acre; nearly half of the observations are estimated to be either 0.001 or 0.01 acre in extent. The total estimated area of the infestations documented in the six survey efforts is estimated to be 63 acres. While the documented extent of invasive plants is limited in the SNK ecoregion, surveys of additional areas presumably would reveal non-native plant species in many other locations as well; the available data should be assumed to be an incomplete picture of current extent of invasive plants.

Figure 4-19. Records of invasive plant species documented in the SNK ecoregion.

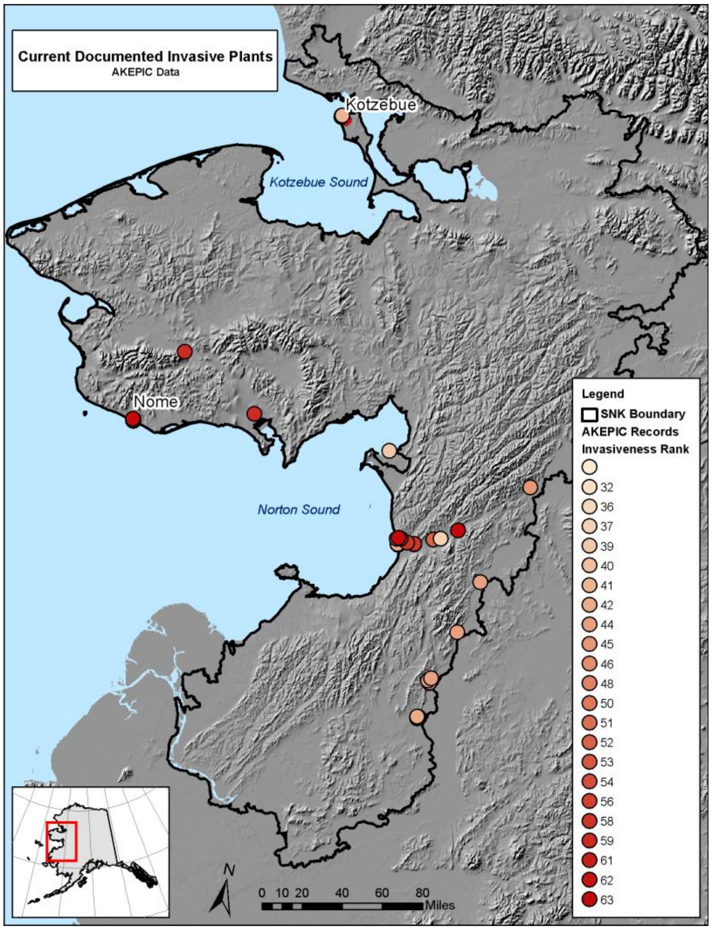


Table 4-7. Counts of observations of non-native plant infestations documented in the SNK ecoregion in the AKEPIC data set. Note: Not all non-native plants documented in the SNK have been ranked for invasiveness yet (see list of ranked species in Carlson et al. 2008).

Scientific Name	Common Name	Invasiveness Rank	Count
Bromus inermis Leyss.	smooth brome	62	1
Capsella bursa-pastoris (L.) Medik.	shepherd's purse	40	3
Chenopodium album L.	lambsquarters	37	20
Crepis tectorum L.	narrowleaf hawksbeard	56	7
Descurainia sophia (L.) Webb ex Prantl	herb sophia	41	1
Elymus repens (L.) Gould	quackgrass	50	1
Galeopsis tetrahit L.	brittlestem hempnettle	50	1
Hordeum jubatum L.	foxtail barley	63	24
Hordeum vulgare L.	common barley	39	1
Leucanthemum vulgare Lam.	oxeye daisy	61	3
Matricaria discoidea DC	pineappleweed	32	26
Papaver croceum Ledeb.	Icelandic poppy	Not ranked	1

Scientific Name	Common Name	Invasiveness Rank	Count
Phleum pratense L.	timothy	54	1
Plantago major L.	common plantain	44	20
Poa annua L.	annual bluegrass	41	3
Poa pratensis L. ssp. *irrigata* (Lindm.) H. Lindb. or *Poa pratensis* L. ssp. *pratensis*	spreading bluegrass or Kentucky bluegrass	52	3
Polygonum aviculare L.	prostrate knotweed	45	7
Rumex acetosella L.	common sheep sorrel	51	1
Rumex crispus L.	curly dock	48	1
Senecio vulgaris L.	common groundsel	36	1
Stellaria media (L.) Vill.	common chickweed	42	11
Taraxacum officinale F.H. Wigg. ssp. *officinale*	common dandelion	58	18
Trifolium pratense L.	red clover	53	1
Trifolium repens L.	white clover	59	11
Tripleurospermum inodorum (L.) Sch. Bip.	scentless chamomile	48	2
Trollius europeus L.	European globeflower	Not ranked	1

143: What are the known and likely introduction vectors of invasive species?

Invasive plant species are a growing threat to biodiversity in SNK; this may be especially true in sites such as riparian areas and mesic meadows that have been disturbed (Conn et al. 2010, Spellman and Wurtz 2010). A primary introduction vector of invasive plant species propagules in Alaska as a whole is the transportation and use of hay and straw as livestock forage (winter feed for cattle), horse feed (especially pack animals for hunting camps), and bedding for sled dogs (Conn et al. 2010, Flagstad and Cortes-Burns 2010). Sled dog bedding is the method of direct introduction relevant in the SNK ecoregion. (This is illustrated in the survey data for the Iditarod Trail, compiled in the AKEPIC data set summarized above.) Many potentially problematic invasive species are found in hay and straw such as *Avena sativa, Brassica rapa, Bromus inermis, Bromus tectorum, Crepis tectorum, Elymus repens, Galeopsis tetrahit, Descurainia sophia), Hordeum jubatum, Hordeum vulgare, Lolium* spp*., Medicago sativa, Phleum pratense*, and *Poa* spp. Flagstad and Cortes-Burns (2010) found that although most invasive species propagules germinated, they did not persist unless the site was disturbed, either anthropomorphically (roadside reclamation, mines, cabin check points and bedding sites along the Iditarod National Historic Trail) or otherwise. Human-induced or natural erosion processes that expose mineral soil appeared to facilitate the establishment of invasive species (Conn et al. 2010, Flagstad and Cortes-Burns 2010). Hay and straw from both Alaska and Oregon both had significant invasive species seeds (Conn et al. 2010). Recommendations include requiring use of weed-free hay, straw, and crop seed to minimized new introductions of new invasive species via this vector (Conn et al. 2010).

Spellman and Wurtz (2010) studied the invasive legume *Melilotus alba*, which is commonly found in hay, and can dominate on naturally disturbed river banks that were scoured by winter ice. They found that the dense canopy of *Melilotus alba* shaded out and reduces recruitment of native species including trees and shrubs (*Populus balsamifera, Salix alaxensis)*, grasses (*Festuca rubra*) and forbs (*Chamerion latifolium, Hedysarum alpinum, Hedysarum boreal spp. mackenzii,* and *Oxytropis campestris*). They recommended management of *Melilotus alba* at road-river interfaces to preserve the biodiversity and structure of these early-successional plant communities. *Melilotus alba* is one of the two species that received bioclimate envelope models in this REA in order to determine whether there are areas of the

SNK that are likely to have the temperature and precipitation "envelopes" in which this species typically occurs.

Five invasive aquatic organisms have been documented elsewhere in Alaska, and they have a variety of modes of introduction and spread. Red swamp crayfish (known from the Kenai Peninsula) may be introduced as bait, when aquarium pets are released, or when used for culinary purposes (NBII and ISSG 2011). Whirling disease affects salmonids; the parasite causing the disease is virtually indestructible, commonly spread via living infected fish but also readily spread by contaminated fishing equipment, and causes direct mortality to the infected fish (NBII and ISSG 2005). It is currently found in the "Anchorage Bowl." In southeast Alaska, the host worm species for *M. cerebralis* (*T. tubifex*) was not encountered, and suitable habitat for the host may be limited; consequently, it is unlikely that whirling disease would become established in this area (Arsan and Bartholomew 2008). Although *T. tubifex* was abundant at many locations in south central Alaska, the varieties documented are primarily non-susceptible lineages, which may reduce the risk of establishment. *Elodea canadensis*, which has been collected from Chena Slough in Fairbanks, is generally initially introduced from aquaria and spreads as stem fragments floating downstream and between catchments via boating equipment (propellers, trailers, etc.), vehicles, or wildlife (Bowmer et al. 1995). While mosquitofish have a range of negative impacts on native species, they are generally not cold tolerant and may require springs to successfully overwinter in cold regions such as Colorado and Nebraska (Woodling 1985, Haynes 1983); consequently, their spread to other parts of Alaska may be limited.

Norway rats, which are documented in Nome, are introduced and spread over larger distances through their associations with humans, via ships and airplanes. Once introduced, they readily establish and spread within urban areas and can also spread easily along beaches or onto islands (Walton and Gotthardt 2011).

4.5.4.2 Nuisance Native Species

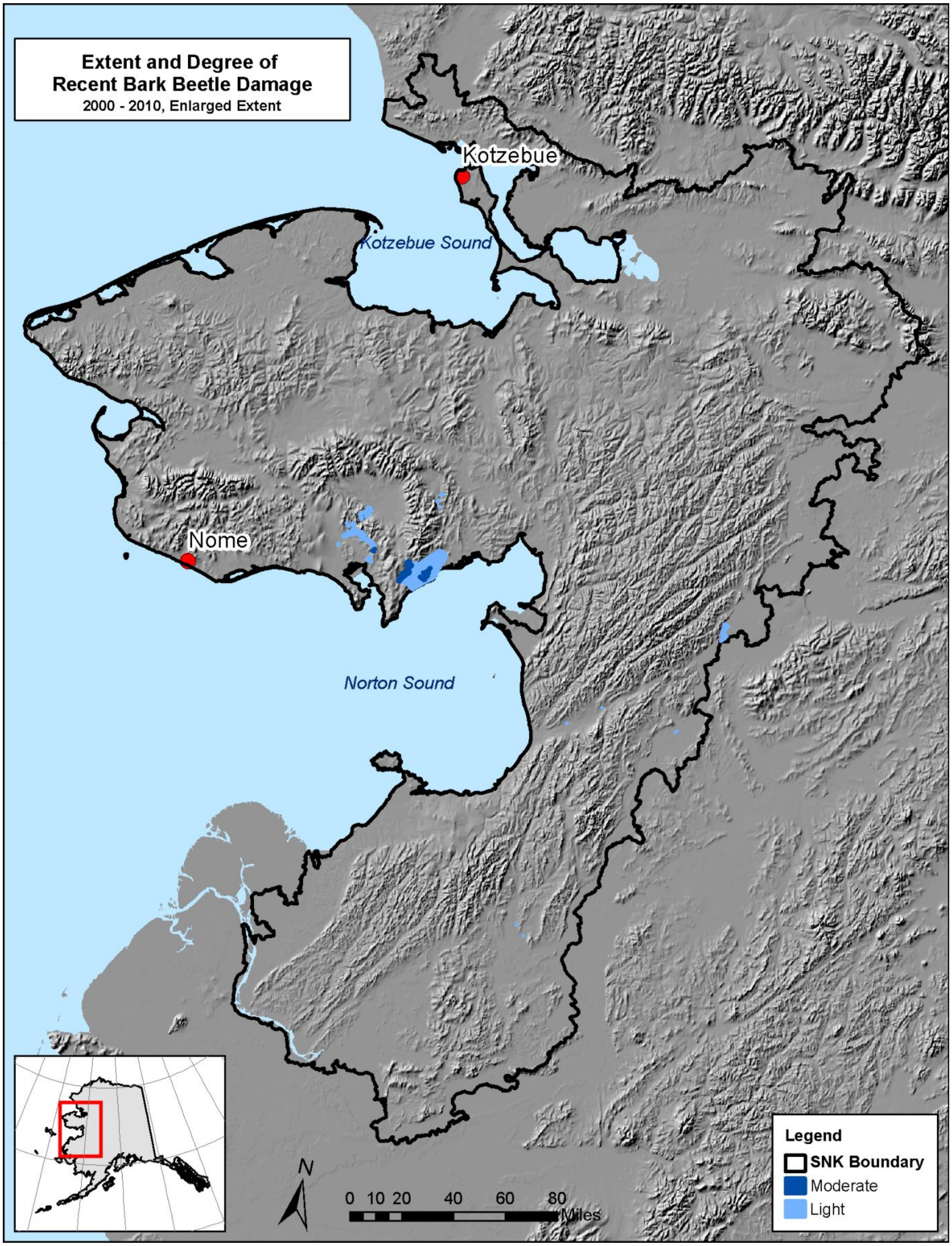
134: Where have recent beetle outbreaks occurred?

Insect and disease epidemics, of both natural and introduced species, are often the result of human-induced changes. For example, climate change has likely increased bark beetle epidemics in spruce ecosystems. The USDA conducts annual forest damage surveys by flying—using fixed-wing aircraft—a predetermined route across Alaska's forests and recording insect damage within one mile on either side of the flight path. Of the listed insects and diseases, adequate information is available from the USDA surveys to illustrate the extent of spruce bark beetle (*Dendroctonus rufipennis*) infestations or damage. (Records for this species were simply selected from the dataset for display.)

While aspen leaf miner has caused the most extensive damage (in aspen) in Alaska overall in recent years, the aerial surveys show spruce bark beetle as having the greatest impact in terms of acreage in the SNK ecoregion, reflecting in part the greater frequency of spruce (relative to aspen) in forested systems in this part of the state. Based on the aerial surveys, approximately 98,500 acres have been affected by spruce bark beetle (Figure 4-20); most of the acreage (~86,000) has been classified as having "light" impact. Surveying the entirety of Alaska's forested landscapes by airplane is not possible; consequently, the extent of insect damage is most likely underestimated. The US Forest Service's Forest Health Protection department has begun studies to identify methods to better estimate the extent of insect damage and infestation (see www.fs.fed.us/wwetac/projects/lundquist.html).

Spruce bark beetles are of management concern because large outbreaks can decimate hundreds of thousands of acres of spruce, including commercially valuable white spruce. Historically, their range has been limited in Alaska by temperature; where the species is present, two cold winters in a row can decrease survival of overwintering insects and greatly reduce the potential for significant outbreaks. With a warming climate, beetle outbreaks have the potential to increase.

Figure 4-20. Extent of bark beetle damage or infestation between 2000 and 2010. Areas shown are slightly enlarged by a thicker outline for visibility.



4.6 CA Relationship to CEs

A series of management questions asking about the relationship of CAs with CEs were identified. A brief summary of how these were addressed in relation to 1) climate, 2) fire, and 3) invasives is provided below. Immediately following this summary, the results of the analysis conducted to address these questions in relation to the development change agent are provided.

> **62**: Where do current CE distributions overlap with CAs?
>
> **68**: What CE populations and movement corridors overlap with CAs?
>
> **105**: Where will current populations of reindeer experience overlap with Change Agents?
>
> **64**: Where are CEs whose habitats are **systematically** threatened by CAs (other than climate change)?

As illustrated by the results of the climate trends modeling, climate change is a pervasive threat in this ecoregion; change has already been documented (as shown in 2020s results in the Future Conditions chapter), and continued change is projected. Broad impacts of these changes to date have been documented in this ecoregion (e.g., 10-km treeline shift per Lloyd et al. 2002). Without knowing a CE's range of tolerance for temperature and precipitation (or other climate variables), a simple spatial overlay of current climate variables (e.g., average January precipitation over the last ten years) with *individual* CE distributions – as implied by "Where do CEs overlap with [climate change] CA? – doesn't yield useful information about climate and CEs. To evaluate climate change at the level of individual CEs, the climate envelope models were identified as the approach for addressing that relationship in this REA; these were proposed for a subset of species CEs. They provide a spatially explicit indication of areas where suitable climate is currently available for these species CEs. (In the Future Conditions chapter, they provide an indication of where suitable climate is projected to be in the future for the select species CEs.)

Fire is a natural ecosystem process; however, in conjunction with climate change, alterations from the reference or natural fire regime are similarly expected to cause substantial changes in ecosystems of this ecoregion. Fire regimes are typically characterized as average return intervals or fire cycles for broad vegetation types (e.g., black spruce cover) or for entire ecoregional units (e.g., Nulato Hills). Rather than attempting to identify an appropriate fire layer to conduct a simple spatial overlay with individual CE distributions, the ALFRESCO model, which evaluates vegetation succession dynamics under the interacting influences of climate, fire, and other variables, was selected as the tool for understanding the relationship between fire (and climate) and vegetation in this REA. These results are discussed in the Fire section in the Future Conditions chapter.

Individual occurrences of invasive species in this ecoregion have been documented as point locations and estimates of areal extent are generally in the range of 0.01 to 0.1 acre in size. (These data are summarized in detail later in this chapter in the Invasives section.) CE distributions for terrestrial coarse-filter CEs and landscape species CEs were modeled at 30-meter pixel resolution. Thirty meter pixels are approximately 0.22 acres in size. Given the variation in the source data sets used to develop the terrestrial coarse-filter CE data layer, there would be a relatively low level of confidence that the point location for a given invasive species covering an area of 0.01 acre was definitively overlapping a particular coarse-filter CE type in the associated 30-meter pixel. The species CE distributions are generally models of *predicted* habitat; again, there would be a low level of confidence that a 0.01 acre invasive plant extent was truly overlapping with a pixel of species' habitat. Finally, the total estimated extent of all invasive plant locations documented as of this REA in the ecoregion is approximately 63 acres – representing 0.0000016% of the ecoregion, and 0.015% of the distribution of the terrestrial coarse-filter CE having the smallest spatial extent in the ecoregion (Arctic Active Inland Dunes). With such a limited known and fine-scale distribution in the ecoregion, summarizing the overlap of currently documented invasive species locations with relatively coarse-scale CE distribution layers would not provide results with an adequate level of confidence to recommend their use in informing ecoregional direction with regard to invasive plant species. Based on the currently available spatial distributions of invasive plant species, it would not appear that any habitats are *systematically* threatened at this time; however, other invasive species management questions elsewhere in the Current and Future Conditions chapters provide a qualitative indication of overall invasive species threats within the ecoregion. In addition, bioclimate models were developed for two invasive plant species with potential to invade this ecoregion; those are discussed in the Invasive Species section in the Future Conditions chapter.

4.6.1 Development Change Agents and CE Distributions

This section addresses the following management questions specifically in relation to the development change agent. Development infrastructure and features have discrete, relatively well-known and mapped footprints and are readily overlaid with individual CEs to assess overlap. The spatial extent of "CE populations" was represented by the models of predicted habitat for individual species (developed by AK GAP) that are used throughout this REA. Caribou seasonal range extents represented the relevant data available to address "movement corridors" for CEs. Reindeer grazing allotments represented the available data on the spatial extent of reindeer populations.

62: Where do current CE distributions overlap with CAs?

68: What CE populations and movement corridors overlap with CAs?

105: Where will current populations of reindeer experience overlap with Change Agents?

64: Where are CEs whose habitats are **systematically** threatened by CAs (other than climate change)?

To look at the area of overlap of CEs with development change agents, the development feature footprints were aggregated and then intersected with each individual CE. In general, there is very little overlap between CEs and current development change agent footprints in the SNK ecoregion, with most CEs having 2% or less of their extent overlapping with development (Table 4-8). Where there is overlap, it is typically between community footprints and CEs. This may be in part because the community footprint polygons are more extensive than the actual extent of the community. Trails and the military areas also commonly overlapped conservation elements. Seabird colonies were the CE having the highest proportion (8.4%) of their total estimated extent overlapped by development footprints. This is due to the fact that communities are predominantly located along the coast where seabird colonies are also located, and the community footprints (which were obtained from Tiger census data and therefore are larger than the actual extent of the communities) were not removed from the mapped distribution of seabird colonies. (If they had been removed, it would have underestimated the actual extent of seabird colonies.)

In general, limitations of these results stem from the accuracy of the mapped development footprints and the accuracy of the mapped CEs. (Discussions of accuracy of mapped CE extents are included with their methods summaries in Appendix B; discussions of mapped accuracy of development change footprints are include with the methods for mapping change agent distributions in Appendix A.)

This simple intersection assessment characterizes the direct overlap of development CAs with CEs, but does not provide any indication of the effects of development CAs on CEs. The earlier section on the Landscape Condition Model, which is used as an indicator in the Ecological Status Assessments in the following section, provides an estimation of the relative impact of these development footprints (and their off-site effects) on CEs.

Table 4-8. Percent of each CE's extent overlapped by <u>current</u> development CAs. Wherever current development footprints overlapped each other they were categorized and summarized as Multiple Development Change Agents. Percent overlap was derived from an overlay of *raster* CE distribution data by *raster* development change agent footprints; therefore the total extent of CEs (even linear features) is summarized as total area (in acres). For ease of reading, the following formatting has been applied:

- **Where development overlaps more than 2% of a CE's total extent, the total percentage of the CE having overlap with development (Total Development Footprint) and the corresponding percentage having no overlap with development (No Development Change Agent) are bolded.**
- **For each CE, the one to three development types having the greatest percent overlap are bolded.**

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agent	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site
Aquatic Coarse Filter												
Headwater Streams	1,285,504	0.773%	99.227%	0.008%	**0.532%**	**0.141%**	0.066%	0.012%	0.012%	-	0.002%	-
Low-Gradient Streams	371,777	0.916%	99.084%	0.012%	**0.528%**	**0.290%**	0.046%	0.027%	0.012%	-	-	-
River	91,989	0.785%	99.215%	0.009%	**0.408%**	**0.219%**	0.024%	0.083%	0.040%	-	0.001%	-
Estuary	16,419	**3.936%**	**96.064%**	0.066%	**2.580%**	**1.258%**	-	0.031%	-	-	-	-
Lakes: Large and Connected	614,831	0.765%	99.235%	0.005%	**0.634%**	**0.126%**	-	-	-	-	-	-
Lakes: Large and Disconnected	119,200	0.826%	99.174%	0.004%	**0.726%**	0.096%	-	-	-	-	-	-
Lakes: Small and Connected	78,124	0.937%	99.063%	0.004%	**0.805%**	**0.126%**	0.002%	0.001%	-	-	-	-
Lakes: Small and Disconnected	271,994	1.419%	98.581%	0.012%	**1.259%**	**0.142%**	0.004%	0.001%	-	-	-	-
Hot Springs	2	-	100.000%	-	-	-	-	-	-	-	-	-
Aquatic Fine Filter												
Arctic Char	451	-	100.000%	-	-	-	-	-	-	-	-	-
Alaska Blackfish	408,411	1.122%	98.878%	0.013%	**0.855%**	**0.250%**	-	0.002%	0.001%	-	-	-
Chinook Salmon	89,413	1.941%	98.059%	0.055%	**1.456%**	**0.419%**	-	0.006%	0.004%	0.001%	-	-

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agent	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site
Chum Salmon	89,027	**2.278%**	**97.722%**	0.072%	**1.488%**	**0.521%**	0.131%	0.051%	0.011%	-	0.004%	-
Coho Salmon	73,684	1.082%	98.918%	0.005%	**0.731%**	**0.199%**	0.018%	0.106%	0.020%	-	0.003%	-
Dolly Varden	612,581	0.558%	99.442%	0.004%	**0.285%**	0.097%	**0.129%**	0.025%	0.015%	-	0.003%	-
Pink Salmon	58,145	**2.550%**	**97.450%**	0.106%	**1.608%**	**0.724%**	-	0.082%	0.022%	-	0.008%	-
Sheefish	26,163	**3.866%**	**96.134%**	0.159%	**2.870%**	**0.837%**	-	-	-	-	-	-
Sockeye Salmon	18,693	**3.652%**	**96.348%**	0.234%	**2.502%**	**0.795%**	-	0.075%	0.025%	0.002%	0.019%	-
Terrestrial Coarse Filter - Ecological Systems												
Arctic Active Inland Dunes	4,044	-	100.000%	-	-	-	-	-	-	-	-	-
Boreal Mesic Birch-Aspen Forest	1,145,389	0.824%	99.176%	0.009%	**0.740%**	0.074%	-	-	-	0.002%	-	-
Boreal White or Black Spruce - Hardwood Forest	1,148,553	1.597%	98.403%	0.006%	**1.546%**	0.044%	-	-	-	-	-	-
Arctic Acidic Sparse Tundra	585,060	0.256%	99.744%	0.003%	**0.146%**	0.078%	0.021%	-	0.005%	0.003%	-	-
Arctic Dwarf Shrubland	1,907,555	1.049%	98.951%	0.007%	**0.466%**	0.064%	0.474%	0.019%	0.013%	0.001%	0.005%	-
Arctic Mesic-Wet Willow Shrubland	1,274,262	1.158%	98.842%	0.012%	**0.742%**	**0.275%**	0.083%	0.035%	0.007%	0.004%	-	-
Arctic Scrub Birch-Ericaceous Shrubland	6,118,469	0.476%	99.524%	0.006%	**0.193%**	**0.163%**	0.062%	0.030%	0.013%	0.001%	0.007%	-
Arctic Mesic Alder	2,464,508	0.642%	99.358%	0.009%	**0.520%**	0.077%	0.011%	0.016%	0.006%	-	0.002%	-
Arctic Dwarf Shrub-Sphagnum Peatland	1,123,465	1.848%	98.152%	0.011%	**1.749%**	0.087%	-	-	-	-	-	-

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agent	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site
Arctic Coastal Brackish and Tidal Marsh	217,717	**6.107%**	**93.893%**	0.056%	**5.584%**	**0.441%**	-	0.019%	-	0.006%	-	-
Large River Floodplain	307,652	1.115%	98.885%	0.020%	**0.964%**	**0.130%**	-	-	0.001%	0.001%	-	-
Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra	3,204,507	0.364%	99.636%	0.001%	**0.145%**	0.058%	**0.148%**	0.008%	0.001%	0.001%	0.001%	-
Arctic Shrub-Tussock Tundra	6,065,470	0.392%	99.608%	0.003%	**0.239%**	0.141%	-	0.006%	0.001%	-	0.001%	-
Arctic Wet Sedge Tundra	2,730,696	0.963%	99.037%	0.018%	**0.493%**	0.168%	**0.243%**	0.032%	0.006%	0.001%	0.001%	-
Boreal Black or White Spruce Forest and Woodland	5,481,044	0.634%	99.366%	0.004%	**0.560%**	0.067%	-	0.001%	0.001%	-	-	-
Landscape Species												
Alaskan Hare	25,957,195	0.761%	99.239%	0.010%	**0.491%**	0.133%	0.099%	0.018%	0.007%	0.001%	0.003%	-
Arctic Peregrine Falcon	14,241,623	0.764%	99.236%	0.010%	**0.616%**	0.118%	0.009%	0.008%	0.003%	0.001%	0.001%	-
Beaver	34,495,847	0.712%	99.288%	0.008%	**0.482%**	0.126%	0.074%	0.014%	0.005%	0.001%	0.002%	-
Black Bear	15,650,552	0.771%	99.229%	0.007%	**0.681%**	0.082%	-	-	-	0.001%	-	-
Black Scoter	21,405,907	1.075%	98.925%	0.013%	**0.816%**	0.177%	0.041%	0.017%	0.006%	0.001%	0.003%	-
Brown Bear	28,383,268	0.624%	99.376%	0.006%	**0.426%**	0.116%	0.059%	0.011%	0.004%	0.001%	0.001%	-
Bristle-thighed Curlew	15,766,516	0.665%	99.335%	0.009%	**0.308%**	0.155%	0.150%	0.028%	0.010%	0.001%	0.004%	-
Bar-tailed Godwit	24,460,712	0.758%	99.242%	0.009%	**0.477%**	0.137%	0.105%	0.019%	0.007%	0.001%	0.003%	-
Caribou	19,939,569	0.410%	99.590%	0.003%	**0.171%**	0.101%	0.119%	0.010%	0.004%	0.001%	0.001%	-

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agent	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site
Cackling Goose	10,043,921	1.300%	98.700%	0.014%	**1.089%**	0.182%	-	0.011%	0.003%	0.001%	0.001%	-
Common Eider	3,681,542	1.251%	98.749%	0.038%	**0.934%**	0.225%	0.002%	0.037%	0.012%	0.002%	0.002%	-
King Eider	11,620,079	0.634%	99.366%	0.011%	**0.184%**	**0.202%**	0.175%	0.041%	0.014%	0.002%	0.006%	-
Moose	25,704,851	0.655%	99.345%	0.006%	**0.384%**	0.142%	0.098%	0.016%	0.006%	0.001%	0.003%	-
Muskox	19,655,035	0.400%	99.600%	0.003%	0.108%	**0.123%**	0.131%	0.022%	0.008%	0.001%	0.004%	-
Yellow-billed Loon	4,675,498	0.450%	99.550%	0.005%	**0.242%**	**0.184%**	-	0.009%	0.007%	0.001%	0.001%	-
Local Species												
Emperor Goose	1,594,157	1.075%	98.925%	0.055%	**0.625%**	0.236%	-	0.114%	0.032%	0.002%	0.010%	-
Hudsonian Godwit	25,140,903	0.765%	99.235%	0.007%	**0.658%**	0.099%	-	-	0.001%	-	-	-
Kittlitz's Murrelet	6,148,100	0.891%	99.109%	0.009%	0.131%	0.234%	**0.419%**	0.064%	0.022%	0.002%	0.010%	-
McKay's Bunting	12,224,764	1.123%	98.877%	0.015%	**0.777%**	0.121%	**0.161%**	0.032%	0.010%	0.001%	0.006%	-
Red Knot	6,499,270	0.962%	99.038%	0.018%	**0.261%**	0.211%	**0.382%**	0.057%	0.021%	0.002%	0.011%	-
Spectacled Eider	11,684,447	1.058%	98.942%	0.017%	**0.690%**	**0.237%**	0.065%	0.033%	0.011%	0.002%	0.003%	-
Species Assemblages												
Marine Mammal Haul-out Sites	40,491	1.112%	98.888%	0.023%	**0.533%**	**0.547%**	-	-	-	0.009%	-	0.001%
Seabird Colonies	374,130	**8.374%**	**91.626%**	0.155%	**7.425%**	**0.669%**	0.055%	0.051%	0.013%	0.007%	-	-
Waterfowl Concentration Areas	10,411,365	1.198%	98.802%	0.018%	**0.979%**	0.175%	0.014%	0.009%	0.002%	0.001%	0.001%	-
Reindeer												
Reindeer Grazing Allotments	14,017,033	0.746%	99.254%	0.012%	**0.294%**	**0.201%**	0.184%	0.036%	0.012%	0.002%	0.005%	-
Caribou												
WAH Caribou: Migratory Range	3,085,591	0.795%	99.205%	0.009%	**0.588%**	0.197%	-	-	-	-	-	-
WAH Caribou: Winter Range	14,201,019	0.175%	99.825%	0.002%	0.077%	**0.093%**	-	-	0.002%	0.001%	-	-

4.7 Ecological Status of Conservation Elements

Although the management question specifically addressing ecological status was framed by the AMT around aquatic CEs, the intent of the REAs is to describe the status of all CEs. In the SNK REA, both terrestrial and aquatic CEs received ecological status assessments.

114: What is the condition of these various aquatic systems [aquatic CEs]?

As stated previously, "ecological integrity" is defined as the ability of an ecological system to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion. In the REA, "ecological status" is the term used for measuring ecological integrity of each CE individually as it occurs across the ecoregion. Ecological status is measured for individual CEs using criteria and indicators based on their ecological requirements, to the extent that data are available to evaluate the identified indicators. Field-based observation data, such as information on vegetation composition, vegetation structure, seral stage, stream flow, riparian habitat condition, composition of aquatic assemblages, etc. are generally not sufficiently comprehensively available for CEs in this ecoregion, or most ecoregions. (While such data may be available for a very limited geography and/or subset of CEs in a given ecoregion, the intent with REAs is to use consistent approaches and geographically and thematically comprehensive data sets in order to achieve a consistent and comprehensive assessment output for CEs.) Consequently, assessments of ecological status in the SNK ecoregion rely entirely on either 1) models that can apply remotely sensed data to estimate certain indicators, or 2) the use of mapped, anthropogenic land uses or infrastructure features that can serve as surrogates for direct indicators of ecological status (e.g., using pollution permits as a surrogate for direct measures of water quality). Available data and modeling tools limited the indicators that could be evaluated at the level of *individual* CEs to a suite of discrete, mapped anthropogenic stressors (e.g., roads, culverts, contaminated sites, etc.)

A qualitative discussion of the potential impacts of climate change and fire on the current ecological status of CEs is provided at the end of this section. Additional details on the ecological status assessment methods and status assessment map results for additional CEs are provided in Appendix B. The CE conceptual models compiled in Appendix E include their identified indicators.

4.7.1 Ecological Status: Terrestrial Conservation Elements

Ecological status was spatially assessed for the terrestrial CEs at the scale of the 2 x 2 km grid cells used as one of the spatial reporting units. Landscape condition was the only indicator that could be modeled or assessed for individual terrestrial CEs. As with other ecological status indicators used to assess aquatic CEs, the landscape condition indicator is scored from high (1.0) to low (0.0) values for the distribution of each CE within each 2 x 2 km grid cell. Higher scores indicate relatively higher ecological status. The landscape condition scores are an area-weighted average calculated from the CE's actual distribution within the 2 x 2 pixel. A subset of priority terrestrial coarse-filter CEs were assessed with this indicator, as well as all landscape species CEs. (Local species whose distributions were available only as point locations (rare plants, one fish species) were not assessed.)

Human development is sparse in the ecoregion and highly clustered around Nome. The lowest condition scores were observed around Nome, its three roads, and other communities in the ecoregion. The mean value for the ecoregion is 0.95, reflecting the high landscape condition and relatively undeveloped nature in the ecoregion. Based solely on this landscape condition indicator, all terrestrial CEs throughout the ecoregion are generally in good to excellent condition.

As noted earlier, there are two primary limitations to the landscape condition index or indicator. First, the impact of a disturbance at a site is subjective and based upon expert opinion as to how a disturbance is scored. The weighting applied in this model is based upon the criteria used in Natural Heritage Methodology to rank an element occurrence in context to the surround landscape. For instance, a road is given a site intensity of 0.5 and distance decay 0.5 (200 meters) while a community (an urban feature with greater impact on the surrounding landscape) is given a site intensity of 0.2 and a distance decay of 0.2 (2,000 meters). Second, these values are considered an overall general score and may not be suitable for all conservation elements; the values are general due to the lack of comprehensive literature describing functions of edge effect or road density and access.

In spite of the limitations of the landscape condition model, the greatly limited extent of development in the ecoregion provides a good degree of confidence that this change agent is having only limited, localized impacts on CEs. Without exception, the vast majority of each CE's distribution has a landscape condition of 0.9 or better. As expected in this ecoregion, where the human footprint and activities occur across a small portion of the ecoregion, most of these CEs' distributions score in the highest interval. A few, such as Large River Floodplain and Arctic Coastal Brackish Meadow, do show some indications of limited impacts by having a more substantial number of pixels scores in lower intervals. CEs are assumed to experience localized effects from development impacts; the condition results for individual CEs may be reviewed in detail to locate the general areas where greater impact (lower condition scores) is expected. Landscape condition for a sampling of CEs is illustrated in the following sections in this chapter. Maps illustrating landscape condition for a broader array of CEs is provided in Appendix B; landscape condition outputs for **all** CEs were included in the data packages for terrestrial and aquatic CE status assessments.

4.7.1.1 Terrestrial Coarse-Filter CEs

Landscape condition indicator results for terrestrial coarse-filter CEs are shown in Table 4-9. To aid review, the most frequent score interval is bolded. For example, 30,105 of the grid cells in which Alaska Arctic Scrub Birch-Ericaceous Shrubland occurs had average condition scores[8] that fell within the 0.9 – 1 score interval (out of 33,613 total grid cells), suggesting that the vast majority of this CE's distribution (90%) is in near-pristine condition. Again, based solely on this indicator, the terrestrial coarse-filter CEs as a whole are expected to be in excellent condition.

---

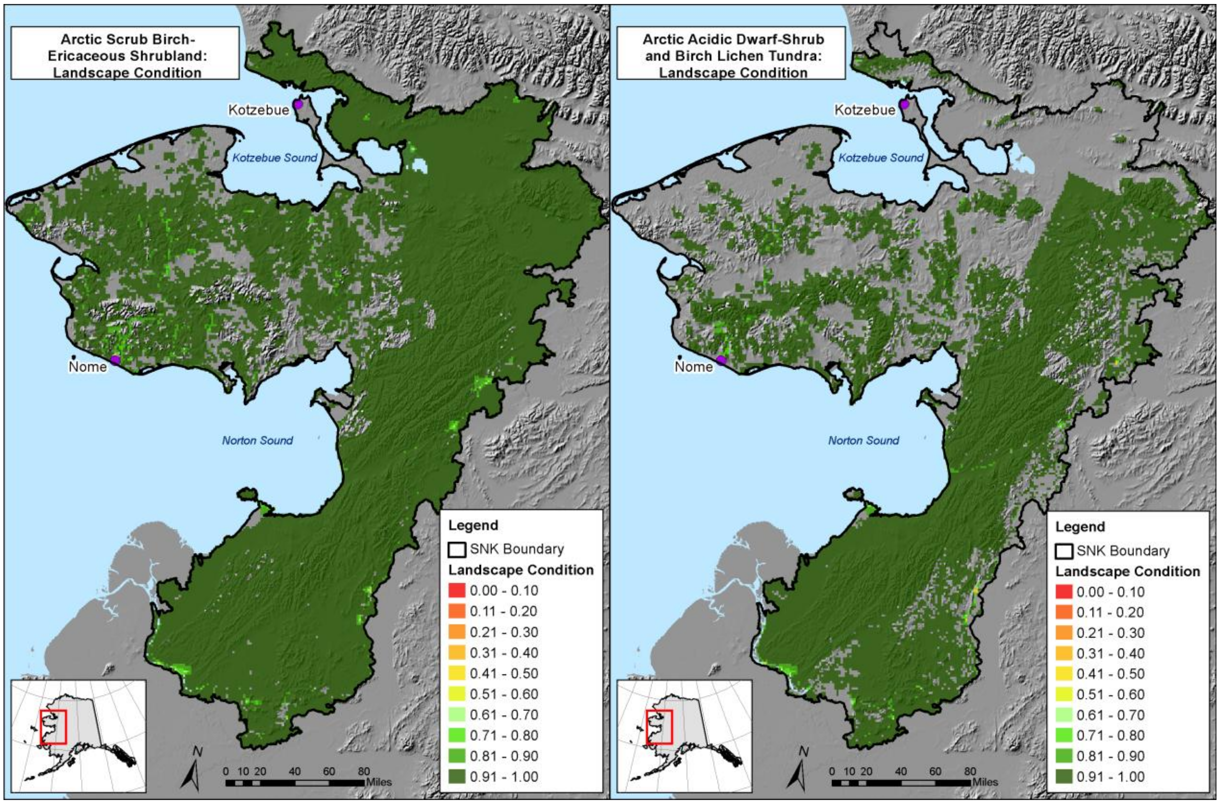
[8] As described in the detailed methods for using the landscape condition model as an indicator in Appendix B, the 2 x 2 grid cell reporting units are scored by taking the average of the condition values for each of the 30 meter pixels of the CE that are present within the 2 x 2 grid cell. So if there are three 30 meter pixels of a CE within a 2 x 2 grid cell, the average of those is taken; if there are nineteen 30 meter pixels of the CE within a 2 x 2 reporting unit, the average of those is taken. The number of 2 x 2 grid cells having average condition values within each of the intervals as shown in Table 4-9 was then tallied.

Table 4-9. Landscape condition indicator results by 2 x 2 km grid cell for terrestrial coarse-filter CEs. The count of 2 x 2 km grid cells is shown for each CE, broken out by indicator score interval. Within each CE group (upland, lowland, coastal), the CEs are sorted by their total number of grid cells, with the most abundant at the top.

	Count of 2 x 2 km grid cells by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
KEA: Landscape Condition											
Landscape Condition Index											
Upland											
Arctic Scrub Birch-Ericaceous Shrubland	33,613				1	3	7	31	126	598	**32,847**
Arctic Mesic Alder	23,074					2	3	30	134	406	**22,499**
Arctic Dwarf-Shrubland	22,256					1	7	23	95	310	**21,820**
Boreal Black or White Spruce Forest and Woodland	21,874						2	6	50	228	**21,588**
Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra	21,805					5	4	15	85	332	**21,364**
Boreal Mesic Birch-Aspen Forest	18,035					1		6	55	186	**17,787**
Boreal White or Black Spruce - Hardwood Forest	16,015							4	36	178	**15,797**
Boreal Spruce-Lichen Woodland	15,127					1		4	41	130	**14,951**
Arctic Mesic Tundra	12,540					1	4	13	42	122	**12,358**
Arctic Lichen Tundra	8,105				2	3	7	9	35	93	**7,956**
Bedrock Cliff, Talus, and Block Fields	6,285				1	1	12	23	77	167	**6,004**
Arctic Acidic Sparse Tundra	2,542							5	23	67	**2,447**
Arctic Active Inland Dunes	29										**29**
Lowland											
Arctic Wet Sedge Tundra	33,447				1	1	16	56	181	739	**32,453**
Arctic Mesic-Wet Willow Shrubland	27,474						3	31	144	539	**26,757**
Arctic Shrub-Tussock Tundra	24,492					1	4	10	64	284	**24,129**
Arctic Dwarf-Shrub-Sphagnum Peatland	13,955					2	3	20	76	221	**13,633**
Boreal Black Spruce Dwarf-Tree Peatland	13,700					1		4	48	199	**13,448**
Arctic Wet Sedge-Sphagnum Peatland	7,228										**7,228**
Large River Floodplain	5,464					1	3	13	47	136	**5,264**
Arctic Freshwater Marsh	3,957						3	9	26	77	**3,842**
Coastal											
Coastal Brackish and Tidal Marsh	1,068						5	4	29	92	**938**
Marine Beach and Beach Meadow	504					1	8	20	53	75	**347**

The index of landscape condition is illustrated in Figure 4-21 for two upland types: Arctic Scrub Birch-Ericaceous Shrubland and Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra.

Figure 4-21. Landscape condition indicator results for Arctic Scrub Birch-Ericaceous Shrubland (left) and Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra (right).



4.7.1.2 Terrestrial Fine-Filter CEs

Of the terrestrial species CEs, all landscape species received status assessments, as well as local species (birds) with distributions mapped as a spatial extent (rather than point locations). These species were a combination of non-subsistence and subsistence species.

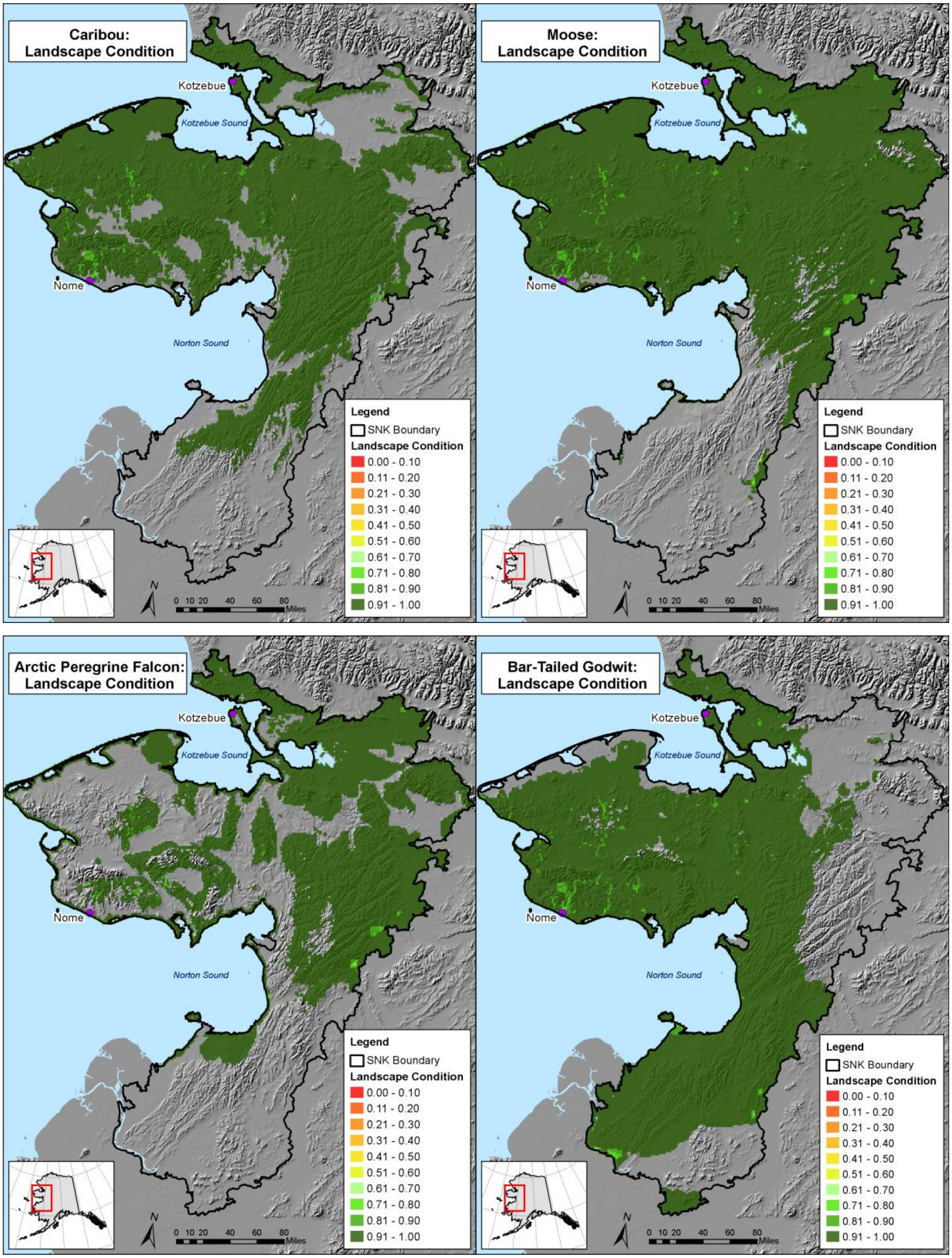
Landscape condition indicator results for landscape species CEs are shown in Table 4-9. As in the other summary tables, to aid review, the most frequent score interval is bolded. For example, the predicted habitat distribution for moose had 28,791 grid cells having weighted average scores that fell within the 0.9 – 1 score interval (out of 29,524 total grid cells), suggesting that the vast majority (98%) of this CE's predicted habitat is in near-pristine condition. Again, based solely on this indicator, the predicted habitat distributions for landscape species CEs as a whole are expected to be in excellent condition.

Table 4-10. Landscape condition indicator results by 2 x 2 km grid cell for terrestrial *landscape* species CEs (current). The count of 2 x 2 km grid cells is shown for each CE, broken out by indicator score interval. Subsistence species are italicized.

	Count of 2 x 2 km grid cells by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
KEA: Landscape Condition											
Landscape Condition Index											
Mammals											
Alaskan Hare	29,200				1	3	8	34	115	584	**28,455**
Beaver	37,807				1	3	8	36	138	635	**36,986**
Black Bear	19,567						2	10	49	216	**19,290**
Brown Bear	35,442				1	1	13	32	119	598	**34,678**
Moose	29,524				1	3	11	29	112	577	**28,791**
Muskox	21,974					1	5	7	46	358	**21,557**
Western Arctic Caribou	25,461					1	4	16	68	394	**24,978**
Birds											
Arctic Peregrine Falcon	19,096				1	1	9	28	95	369	**18,593**
Bar-tailed Godwit	27,807				1	3	8	29	98	533	**27,135**
Black Scoter	30,071				1	3	9	36	167	739	**29,116**
Bristle-thighed Curlew	18,034				1	3	4	20	65	434	**17,507**
Cackling Goose	17,919					1	7	19	115	401	**17,376**
Common Eider	5,580				1	3	8	28	79	221	**5,240**
King Eider	13,549				1	3	6	22	60	424	**13,033**
Yellow-billed Loon	7,001						2	3	32	143	**6,821**

The index of landscape condition relative to the predicted species habitat is shown in Figure 4-22 for a sampling of landscape species: caribou, moose, Arctic peregrine falcon, and bar-tailed godwit.

Figure 4-22. Landscape condition for caribou (upper left), moose (upper right), Arctic peregrine falcon (lower left), and bar-tailed godwit (lower right).



Landscape condition indicator results for local species CEs are shown in Table 4-11 and species assemblages in Table 4-12. As in the other summary tables, to aid review, the most frequent score interval is bolded. For example, the predicted habitat distribution for Hudsonian godwit had 27,063 grid cells having weighted average scores that fell within the 0.9 – 1 score interval (out of 27,465 total grid cells), suggesting that the vast majority (99%) of this CE's predicted habitat is in near-pristine condition. Again, based solely on this indicator, the predicted habitat distributions for these CEs as a whole are expected to be in excellent condition.

Table 4-11. Landscape condition indicator results by 2 x 2 km grid cell for terrestrial *local* species CEs. The count of 2 x 2 km grid cells is shown for each CE, broken out by indicator score interval.

	Count of 2 x 2 km grid cells by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
KEA: Landscape Condition											
Landscape Condition Index											
Birds											
Emperor Goose	3,157				1	3	4	21	57	173	**2,898**
Hudsonian Godwit	27,465						5	15	89	293	**27,063**
Kittlitz's Murrelet	7,138				1	2	3	16	48	303	**6,765**
McKay's Bunting	14,593				1	3	6	26	75	388	**14,094**
Red Knot	8,496				1	3	4	15	42	318	**8,113**
Spectacled Eider	15,420				1	3	10	32	124	540	**14,710**

Table 4-12. Landscape condition indicator results by 2 x 2 km grid cell for species assemblage CEs. The count of 2 x 2 km grid cells is shown for each CE, broken out by indicator score interval.

	Count of 2 x 2 km grid cells by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
KEA: Landscape Condition											
Landscape Condition Index											
Marine Mammal Haul-out Sites	299						1	2	6	15	**275**
Seabird Colonies	793						4	18	41	85	**645**
Waterfowl Concentration Areas	19,509					3	11	36	141	455	**18,863**

4.7.2 Ecological Status: Aquatic Conservation Elements

Ecological status was assessed for the aquatic CEs at the scale of the 5th level watersheds (10-digit HUCs) used as one of the spatial reporting units. Ecological status indicators are scored from high (1.0) to low (0.0) values for the distribution of each CE within each watershed. Higher scores indicate relatively higher ecological status. Available data limited the set of indicators that could be assessed to the following: 1) flow modification by culverts, 2) index of placer mines, 3) index of ditches (for placer mines), 4) pollution permits, and 5) landscape condition. Based on their relevance to the CE, different combinations of the five aquatic indicators were applied to the aquatic CEs and summarized by the 5th level watersheds.

As with terrestrial CEs, both coarse and fine-filter aquatic CEs are generally in excellent condition, based on the five indicators assessed. Again, the vast majority of each CE's distribution scored 0.9 or higher for all five indicators. Flow modification and blockage of fish passage due to culverts occurs in the stream network in highly localized areas around Nome roads; however, this area is a tiny proportion of the affected CEs' distributions. Pollution permits are similarly concentrated around communities, primarily Nome and Kotzebue; very small proportions of CEs are affected. Placer mines and ditches are more broadly distributed in the ecoregion, but are still very limited in extent relative to the size of the ecoregion. As noted for the terrestrial CEs, the small collective development footprint in the ecoregion results in good to excellent landscape condition for aquatic CEs throughout most of the ecoregion. With a population under 20,000 people, and with mining, subsistence practices, and reindeer grazing being the primary land uses in the region, it is not surprising that the indicators for which data are available show aquatic CEs to be in excellent condition.

4.7.2.1 Aquatic Coarse-Filter CEs: Ecological Status

Complete indicator results for aquatic coarse-filter CEs are shown in Table 4-13. Results and limitations are described here for each indicator and apply to both coarse- and fine-filter aquatic CEs.

4.7.2.1.1 Landscape Condition Index

Human development is sparse in the ecoregion and highly clustered around Nome. The lowest scores were observed in the Nome River watershed (0.77), Snake River (0.79) and Outlet Kougarok River (0.85). As with the other metrics, the lowest potential value is 0, a value only observed in urban areas or mines. The mean value for the ecoregion is 0.95, reflecting the high landscape condition and relatively undeveloped nature in the ecoregion.

As noted earlier, there are two primary limitations to this approach for assessing landscape condition. First, the impact of a disturbance at a site is subjective and based upon expert opinion as to how a disturbance is scored. The weighting applied in this model is based upon the criteria used in Natural Heritage Methodology to rank an element occurrence in context to the surround landscape. For instance, a road is given a site intensity of 0.5 and distance decay 0.5 (200 meters) while a community (an urban feature with greater impact on the surrounding landscape) is given a site intensity of 0.2 and a distance decay of 0.2 (2,000 meters). Second, these values are considered an overall general score and may not be suitable for all conservation elements; the values are general due to the lack of comprehensive literature describing functions of edge effect or road density and access.

4.7.2.1.2 Index of Placer Mine Ditches

Similar to other metrics described here, most watersheds have no ditches and have a score of 1. Those watersheds that do are limited to the Seward Peninsula, although these features tend to be less clustered around Nome and distributed more widely on the Peninsula. Because these features tended to be found in the highest reaches of the watershed, headwater streams and CEs more closely associated with headwaters (e.g. Dolly Varden) could be disproportionally affected by these features. For the headwater streams CE, the Headwaters Kougarok River watershed and the Outlet Kiwalik River watershed have the largest total ditch lengths (and therefore scored at or near 0), followed by the Inmachuk River watershed. Since total ditch length across a watershed was assessed and applied to the entire CE, coho salmon showed the same patterns in the watersheds where it is predicted to be present; the Headwaters Kougarok River watershed is the worst-scoring watershed where coho are expected to be present.

Uncertainty regarding this metric largely stems from the lack of documented, on-going effects of historical ditches within the ecoregion. Looking more broadly, the total length of ditches will act as a proxy for the impacts of historical mining activity in the ecoregion, especially in the absence of data regarding the mining impacts on the aquatic resources of the region.

4.7.2.1.3 Index of Fish Passage (culverts)

Culverts are not common in the ecoregion. Consistent with other human infrastructure, culverts are limited to the seasonal roads and highways connecting Nome with the villages on the Seward Peninsula. The vast majority of watersheds scored the highest value of one with only 14 watersheds scoring less than 1. The watersheds most affected by culverts are the Nome River (0), headwaters of the Pilgrim River (0.22) and Solomon River (0.81). The high number of culverts is likely a serious impact to fish and aquatic life in these streams.

This metric uses recent information gathered in the field by AK F&G staff. The high accuracy of this information makes it particularly important as a metric for gauging the connectivity of streams in the region.

4.7.2.1.4 Index of Placer Mines

There are 380 known mines in the ecoregion, the vast majority on the Seward Peninsula. Only 26 of these mines are currently active according to the ARDF. During the May, 2012 AMT workshop, the AMT agreed to include inactive as well as active mines as many inactive mines are still significant sources of sedimentation and acid drainage. While much of the concern regarding placer mines focuses on active mines, the region contains many historical mines which have never been reclaimed and continue to erode steadily, potentially generating similar issues as observed in active mines, although at a diminished level.

The results of this metric reveal that mines are highly clustered in areas on the Seward Peninsula. The majority of watersheds scored have no mines and therefore maintain a score of 1. For one of the most extensive CEs, headwater streams, the lowest scoring watershed is the Snake River (score of 0, 62 mines, seven of which are still active). Other watersheds with significant mining are Nome (0.2), Headwaters of the Pilgrim River (0.4), and Solomon (0.48).

The metadata with the mining data did not always reveal the current status of the mine, although it appears that the ARDF is periodically updated to include new mines and remove those that have ceased to operate. It is not unreasonable to assume that placer mines operate seasonally and often experience lengthy periods of inactivation. While the downstream effects of placer mines are well documented in Alaska, there was little current data and no documented downstream effects within the ecoregion. Another source of uncertainty is the quantity and quality of discharge water to streams itself. An EPA report on Alaska placer mining (EPA 1992) notes that discharge from placer mines may vary considerably depending on the individual practices of the mine operator and the sophistication of the settling pond system that the operator maintains on site.

4.7.2.1.5 Pollution Permits

The results of this indicator show that most of the watershed is not affected by pollution discharge. The vast majority of watersheds in the ecoregion have no pollution discharge permits. Most pollution discharge occurs in or around Nome and Kotzebue but some coastal and interior villages have a small number of permits (<10). The presence of the urban area of Nome contributes to the lowest scores (0) observed at Safety Sound-Frontal Norton Sound and Nome River (55 permits). The next highest is the June Creek-Frontal Kotzebue Sound with a score of 0.59 (23 permits).

Just outside the ecoregion, water quality issues have been reported in the village of Kivalina but this is due to effluents produced at the nearby Red Dog zinc mine (AKDEP 2006). Any water quality issues within the ecoregion are poorly documented. Most water bodies in the ecoregion did not have sufficient information to make any determinations on water quality based solely on pollution permits. The ecoregion does contain a few “category 3, open file” streams (AKDEP 2010). These streams fall short of category 4 (impaired) status but enough evidence of impairment has been found by one of Alaska's resource management agencies to warrant some concern (e.g., an open file). A few streams included in the category 3 list are mostly found in the gold mining region of the Seward Peninsula: the Nome River, Snake and Solomon Rivers (AKDEP 2010).

Table 4-13. Indicator results by 5th-level watershed for aquatic coarse-filter CEs. For each indicator, the count of HUCs is shown for each CE, broken out by indicator score interval.

	Count of HUCs by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
KEA: Landscape Condition											
Landscape Condition Index											
Estuaries	75										**75**
Headwater Streams	242									1	**241**
Hot Springs	9										**9**
Large Connected Lakes	171										**171**
Large Disconnected Lakes	153									1	**152**
Small Connected Lakes	232									1	**231**
Small Disconnected Lakes	239									1	**238**
Low-gradient Streams	241									1	**240**
Rivers	240									1	**239**
Index of Placer Mine Ditches											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Estuaries	75	1			1	3		2	3	1	**64**
Headwater Streams	242	2			1	4		4	6	7	**218**
Hot Springs	9								1		**8**
Large Connected Lakes	171	1			1	2		4	5	6	**152**
Large Disconnected Lakes	153	1			1			4	3	4	**140**
Small Connected Lakes	232	2			1	3		4	6	7	**209**
Small Disconnected Lakes	239	2			1	4		4	6	7	**215**
Low-gradient Streams	241	2			1	4		4	6	7	**217**
Rivers	240	2			1	4		4	6	7	**216**
KEA: Connectivity											
Index of Fish Passage (culverts)											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Headwater Streams	242	1		1		1	1	2	1	2	**233**
Low-gradient Streams	241	1		1		1	1	2	1	2	**232**
Rivers	240	1		1		1	1	2	1	2	**231**
KEA: Water Quality											
Index of Placer Mines											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Estuaries	75				1		1	1	2	4	**66**
Headwater Streams	242	1			1		3	3	2	6	**226**
Hot Springs	9										**9**
Large Connected Lakes	171				1		1	2	1	6	**160**

	Count of HUCs by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Large Disconnected Lakes	153	1					1	1		4	**146**
Small Connected Lakes	232	1			1		3	3	1	5	**218**
Small Disconnected Lakes	239	1			1		3	3	2	6	**223**
Low-gradient Streams	241	1			1		3	3	2	6	**225**
Rivers	240	1			1		3	3	2	6	**224**
Pollution Permits											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Estuaries	75	1					2				**72**
Headwater Streams	242	2					2			5	**233**
Hot Springs	9										**9**
Large Connected Lakes	171	1					2			2	**166**
Large Disconnected Lakes	153	2					2			2	**147**
Small Connected Lakes	232	2					2			5	**223**
Small Disconnected Lakes	239	2					2			5	**230**
Low-gradient Streams	241	2					2			5	**232**
Rivers	240	2					2			5	**231**

4.7.2.2 Aquatic Fine-Filter CEs: Ecological Status

Indicator results for modeled fish habitats are shown in Table 4-14. Results and limitations are described in the previous section under coarse-filter aquatic CEs.

Table 4-14. Indicator results by 5th-level watershed for aquatic landscape species CEs. For each indicator, the count of HUCs is shown for each CE, broken out by indicator score interval. (Arctic char is a local species, but since locational information was available, relevant indicators were assessed. Stream connectivity was not included since it is a lacustrine species in Alaska.)

	Count of HUCs by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
KEA: Landscape Condition											
Landscape Condition Index											
Alaska Blackfish	199									1	**198**
Arctic Char	2										**2**
Chinook Salmon	128									1	**127**
Chum Salmon	165									1	**164**
Coho Salmon	144									1	**143**
Dolly Varden	230									1	**229**
Pink Salmon	121									1	**120**
Sheefish	59										**59**
Sockeye Salmon	46									1	**45**
Index of Placer Mine Ditches											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Alaska Blackfish	199	1			1	4		4	5	6	**178**
Arctic Char	2								1		**1**

	Total	0-.1	.1-.2	.2-.3	.3-.4	.4-.5	.5-.6	.6-.7	.7-.8	.8-.9	.9-1
	Count of HUCs by score interval										
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Chinook Salmon	128					2		3	3	2	**118**
Chum Salmon	165	1			1	4		4	5	7	**143**
Coho Salmon	144	1				4		2	4	4	**129**
Dolly Varden	230	2			1	4		4	6	7	**206**
Pink Salmon	121	1			1	4		4	4	5	**102**
Sheefish	59								1		**58**
Sockeye Salmon	46					2		1	2	1	**40**
KEA: Connectivity											
Index of Fish Passage (culverts)											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Alaska Blackfish	199	1		1		1	1	2	1	2	190
Chinook Salmon	128	1		1			1	1	1	1	**122**
Chum Salmon	165	1		1		1	1	2	1	2	**156**
Coho Salmon	144	1		1		1	1	2		2	**136**
Dolly Varden	230	1		1		1	1	2	1	2	**221**
Pink Salmon	121	1		1		1	1	2	1	2	**112**
Sheefish	59										**59**
Sockeye Salmon	46	1		1			1			2	**41**
KEA: Water Quality											
Index of Placer Mines											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Alaska Blackfish	199									2	**197**
Arctic Char	2										**2**
Chinook Salmon	128									2	**126**
Chum Salmon	165								1	1	**163**
Coho Salmon	144									3	**141**
Dolly Varden	230			1		1	1	2		5	**220**
Pink Salmon	121								1	2	**118**
Sheefish	59										**59**
Sockeye Salmon	46									2	**44**
Pollution Permits											
	Total	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Alaska Blackfish	199	2					2			4	**191**
Arctic Char	2										**2**
Chinook Salmon	128	2					1			4	**121**
Chum Salmon	165	2					1			5	**157**
Coho Salmon	144	2								5	**137**
Dolly Varden	230	2					1			5	**222**
Pink Salmon	121	2					1			2	**116**
Sheefish	59									2	**57**
Sockeye Salmon	46	2					1			2	**41**

Integrity indicators for a coarse-filter CE, headwater streams, and a fine-filter subsistence species, Coho salmon, are illustrated in Figure 4-23 (Landscape Condition Index for both CEs), Figure 4-24 (remaining indicators for headwater streams), and **Error! Reference source not found.** (remaining indicators for Coho salmon).

Figure 4-23. Landscape condition index or indicator for headwater streams (left) and Coho salmon (right).

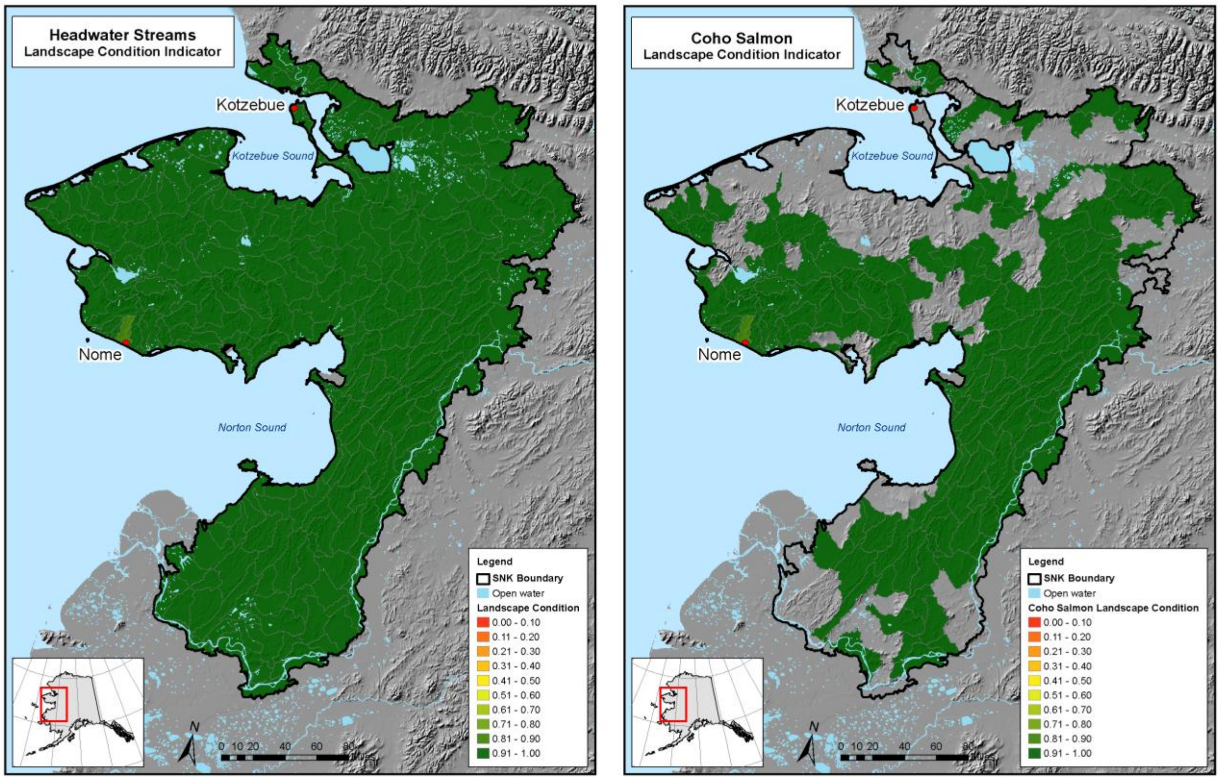


Figure 4-24. Other aquatic indicators for headwater streams: Connectivity/Index of Fish Passage (culverts) (upper left), Index of Placer Mines (upper right), Index of Placer Mine Ditches (lower left), and Pollution Index (pollution permits indicator) (lower right).

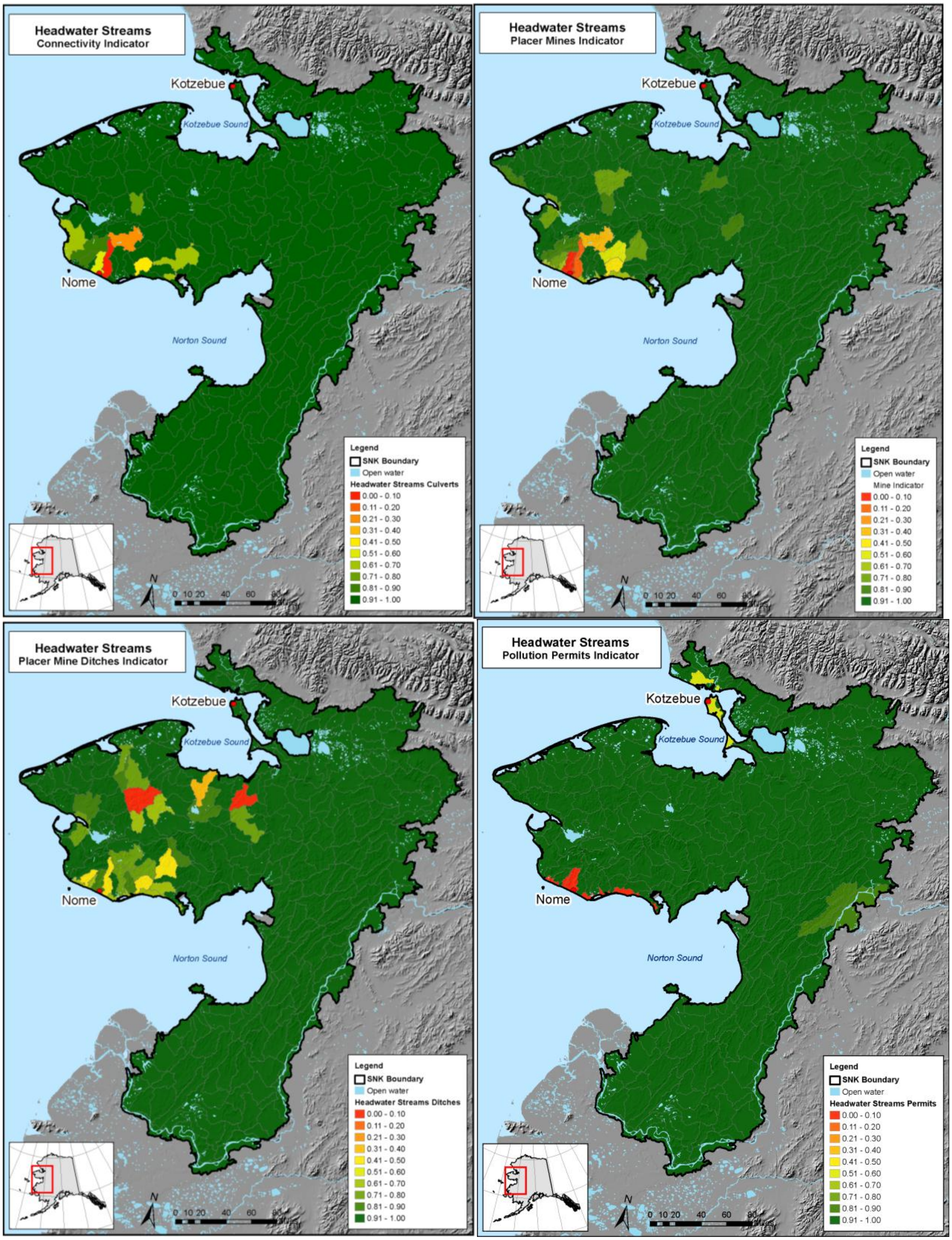
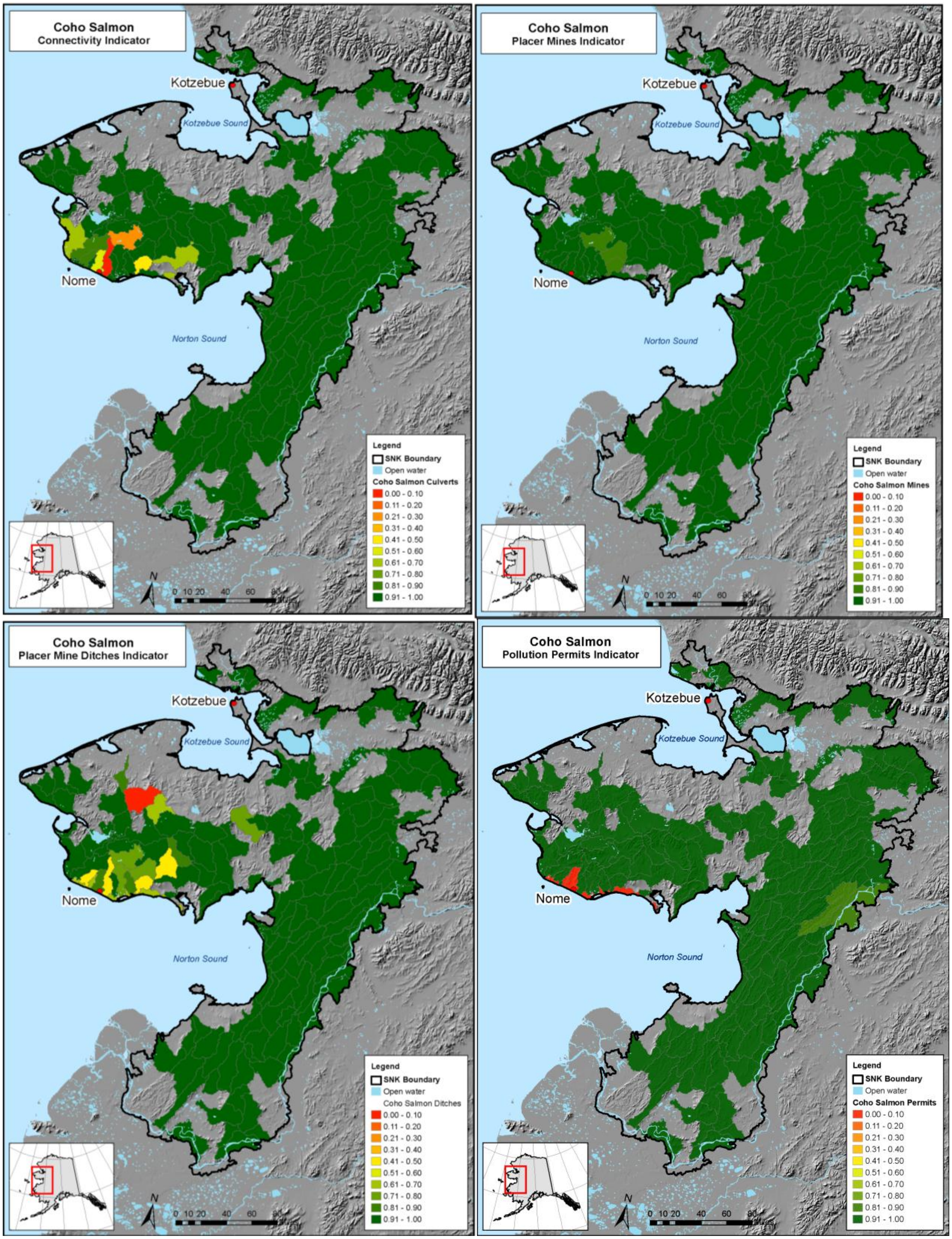


Figure 4-25. Other aquatic indicators for headwater streams: Connectivity/Index of Fish Passage (culverts) (upper left), Index of Placer Mines (upper right), Index of Placer Mine Ditches (lower left), and Pollution Index (pollution permits indicator) (lower right).



4.8 *Ecological Integrity: Current*

Although development is estimated to have had very limited and localized impacts on ecological integrity, impacts resulting from climate change and likely alterations in fire rotation from a “natural” or historical baseline that have taken place to date have been documented. While the *significance* of these effects on current ecological integrity isn’t readily quantified, they appear to be relatively substantial. Development impacts are discussed first, followed by a discussion of likely potential impacts from changes in climate and fire regimes that have taken place to date.

4.8.1 Development Impacts on Integrity

As expected, when reviewing indicators of development stressor impacts across the ecoregion, without reference to individual CEs, they all show a low degree of estimated relative impact on ecological integrity. Landscape condition applies to the integrity of both terrestrial and aquatic systems of the ecoregion, while the remaining indicators apply to the integrity of aquatic systems throughout the ecoregion. Table 4-15 summarizes the count of HUCs in each scoring interval for each indicator; for all indicators, 90% or more of the HUCs score in the highest possible range of values (0.9 – 1).

Table 4-15. Summary of ecological integrity indicator results by 5th-level watershed.. For each indicator, the count of 5th-level watersheds is shown, broken out by indicator score interval.

	Count of 5th-level HUCs by score interval										
Indicator	**Total**	**0-.1**	**.1-.2**	**.2-.3**	**.3-.4**	**.4-.5**	**.5-.6**	**.6-.7**	**.7-.8**	**.8-.9**	**.9-1**
Landscape Condition	243	1								1	**241**
Aquatic Connectivity (culverts)	243	2		1		1	1	2	1	2	**233**
Index of Placer Mine Ditches	243	3			1	4		4	6	7	**218**
Index of Placer Mines	243	2			1		3	3	2	6	**226**
Pollution Index	243	3					2			5	**233**

Figure 4-26 and Figure 4-27, following immediately below, illustrate the scores, by HUC, for each of the five development-related indicators of ecological integrity. The limited impacts that are present as a result of lower landscape condition, aquatic connectivity, and potential pollution are concentrated around Nome and Kotzebue. Impacts resulting from placer mines or associated ditches are distributed somewhat more broadly around the Seward Peninsula portion of the SNK ecoregion.

Figure 4-26. Development-related indicators of ecological integrity summarized and mapped by 5th-level watershed: Landscape Condition (upper left), Aquatic Connectivity (upper right), Placer Mine Ditches (lower left), Placer Mines (lower right).

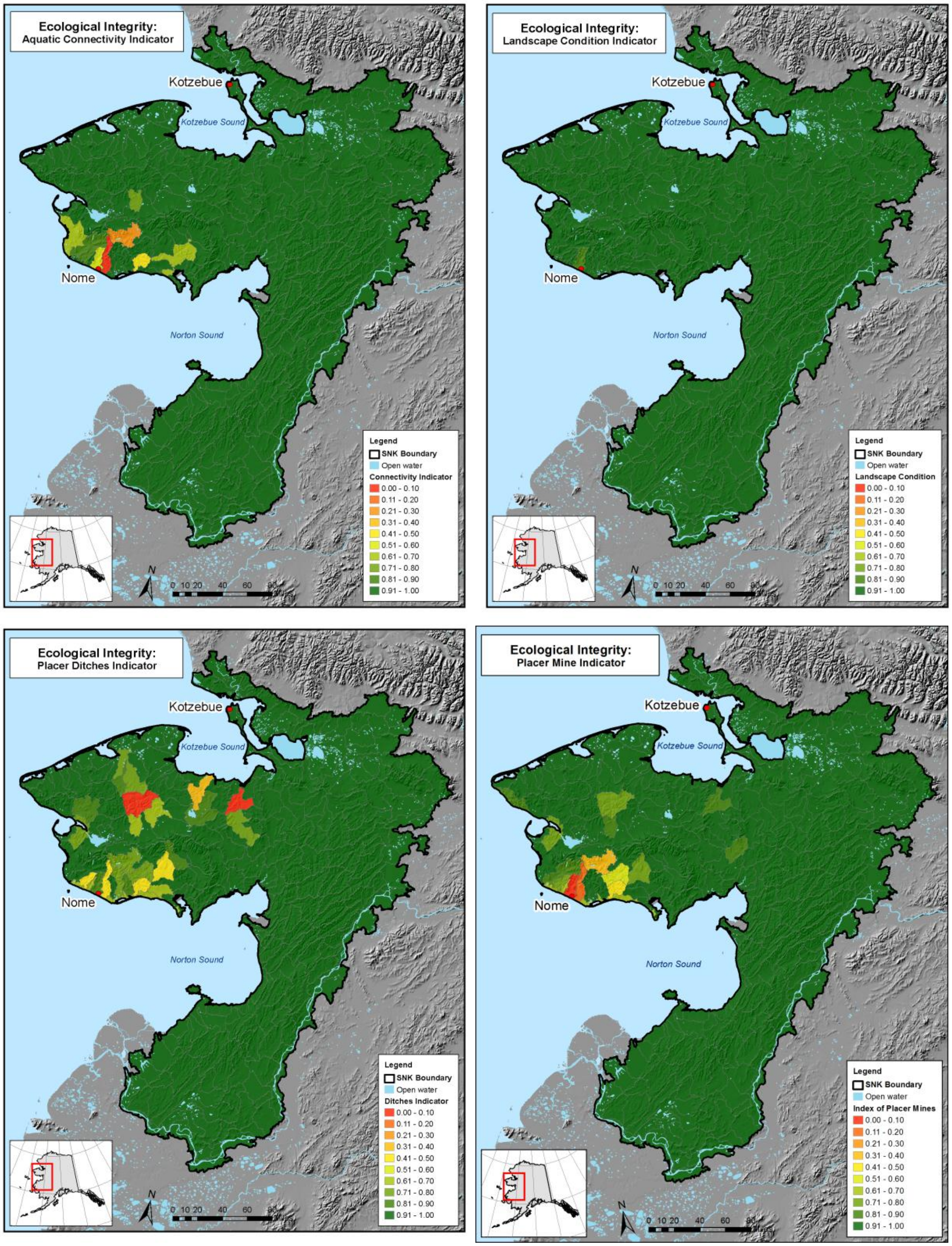
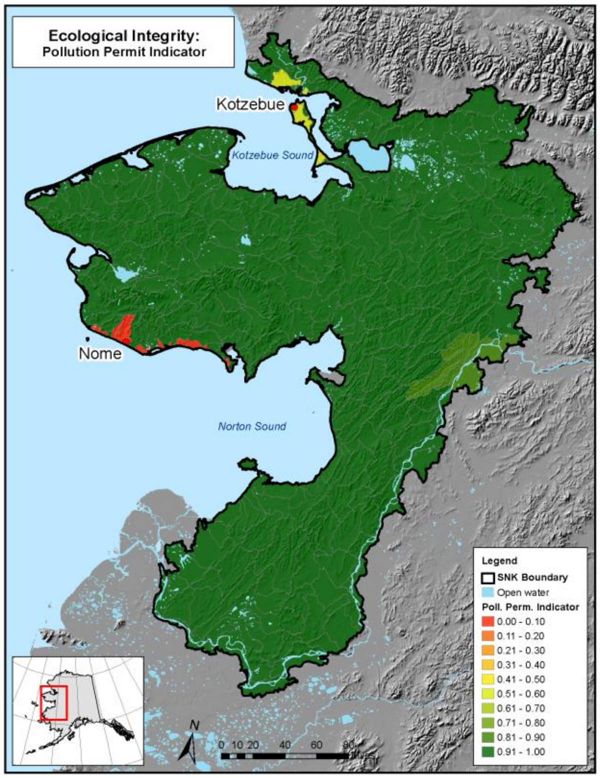


Figure 4-27. Development-related indicators of ecological integrity summarized and mapped by 5th-level watershed, continued: Pollution Permits.



4.8.2 Climate and Fire Impacts on Integrity

Based on the results of the climate and permafrost models conducted for this REA, significant changes in climate and associated changes in permafrost are projected between the baseline period (1901-1980) and the near future (2020s). (The climate and permafrost model results for 2020s and other future time periods are discussed in the Future Conditions chapter.) However, much of the time span between these two periods (1980-2012) is already in the past; therefore, based on the model results, it is clear that climate change has already occurred (and will continue to occur) in the SNK ecoregion. Given the magnitude of this change, as estimated by projected threshold shifts in permafrost conditions (from below to above freezing at one meter depth) and by the high incidence of months projected to have temperature and/or precipitation patterns outside the historical normal range (two standard deviations from the mean), it is very likely that climate change has already affected the current ecological integrity of the ecoregion's ecosystems as a whole.

This theory is supported by the literature, which catalogs numerous ongoing ecosystem changes, including shrubbification, treeline shifts (Lloyd et al. 2002), changing hydrology associated with permafrost change (Jorgenson and Osterkamp 2005, Jorgenson et al. 2010), and changes in lichen growth and associated caribou/reindeer habitat (Joly et al. 2007, 2009, 2010).

Alterations in typical historical fire cycles add another climate-linked factor that is also likely to already be compromising the integrity of ecosystems throughout the ecoregion. Due to the high inter-annual variability of fire on the landscape, it is difficult to pinpoint what is "normal." However, when viewed across long time spans, fire has a profound effect on the overall structure and composition of the vegetative communities on the landscape. Examination of the fire history of the region appears to point to more fires and greater area burned in recent decades than in the more distant past (baseline period). Moreover, model results from ALFRESCO suggest that this change is accelerating. The likelihood that fire cycles are already altered, and impacting vegetative communities, is also supported by the literature, which describes loss of lichens to fire (Jandt et al. 2008; Holt et al. 2008), more frequent fires in forested areas (Rupp et al. 2002, 2006, 2007), and associated habitat shifts (Johnstone et al. 2011).

Considering the combined influences of development, climate change, and alterations in fire regime to date, these changes to ecological integrity appear to be fairly substantial, although the projections for continued climate, permafrost, and fire regime alterations indicate potential for far greater change than what has taken place to date. In some parts of the U.S., wholesale elimination of native ecosystems has taken place, such as in the corn and soybean-producing regions of the Midwest and Great Plains. In other parts of the western U.S. where the land hasn't been directly converted to other uses, the spread of invasive species has drastically altered native ecosystems and resulted in a substantial loss of natural vegetation cover (replaced by invasives). In the SNK, ecosystems are still largely intact in that they haven't undergone wholesale conversion to other uses or a significant degree of invasion by non-native species. However, based on the research summarized above, changes in the composition and structure of terrestrial ecosystems have already been observed as a result of changes in climate and fire processes. The full suite of native species comprising the ecosystems of the SNK is still present; individual species are in the process of climate and fire-mediated shifts in distribution, which is altering the composition of vegetative assemblages. (Ecosystem changes resulting from permafrost loss to date have not been documented, but it is expected that permafrost losses will be a synergistic component of the ecosystem drivers causing continued changes into the future.) It is unclear at this time whether similar shifts are taking place with animal species assemblages, either in aquatic or terrestrial systems. Managing for this type of change presents challenges because the causal agents (climate, fire) are not easily managed. Brief, minimum recommendations for monitoring are noted in the Future Conditions discussion of integrity in order to track and understand ecosystem changes going forward.

5 Potential Future Conditions in the Seward Peninsula – Nulato Hills – Kotzebue Lowlands Ecoregion

Throughout the Current Conditions chapter, the Potential Future Conditions chapter, and Appendices A, B, C, and D, the management question(s) being addressed in a particular section are highlighted as in this example below, with the original MQ number included for reference:

147: What are the potential future climate scenarios for temperature and precipitation?

5.1 *Projected Socioeconomic Profile and Conditions*

This section focuses on the second part of MQ 16, "How are community socio-economic conditions likely to change under development and climate change scenarios?" The first part of MQ 16 (a) was addressed in the corresponding Current Conditions chapter of this report.

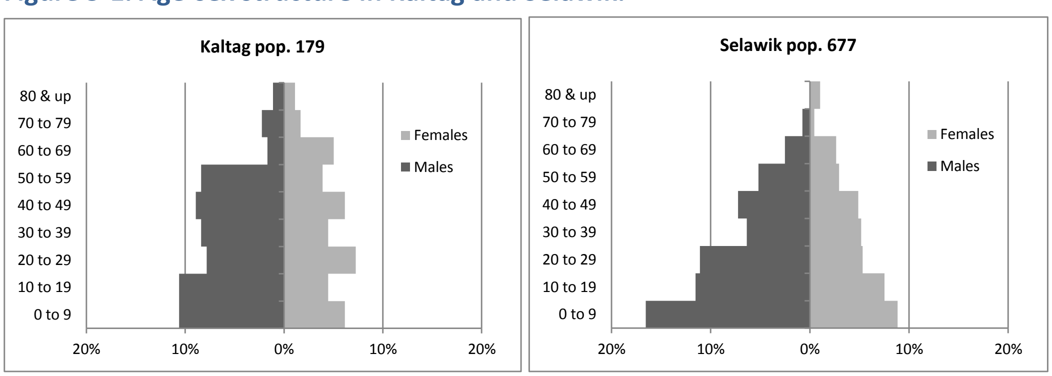
16. (a) What is the current socio-economic profile for each community? (b) How are they likely to change under development and climate change scenarios?

5.1.1 Population and Demographic Structure

More communities are losing population than are gaining, and these trends are expected to continue. The main driver for population change has been net out-migration of young adults, young women in particular. The age-sex structure of some small places shows few young adults (many leave) and does not look promising for future growth. For example, in both Pitkas Point and Deering there is only one Alaska Native[9] female between the ages of 25-29 (U.S. Census Bureau 2011). Other places have more males than females. This is because even though similar numbers of males and females leave rural Alaska, fewer women return. If trends continue, most small communities will continue to lose population.

Figure 5-1 shows gender imbalance in Kaltag, where there are 1.5 males per female and Selawik with 1.6 males per female (U.S. Census Bureau 2011). Even though Selawik is a relatively large community, males outnumber females. Population structure graphs for other communities in the SNK ecoregion are included in Appendix D.

Figure 5-1. Age-sex structure in Kaltag and Selawik.



[9] Alaska Native includes Alaska Native and 2 or more races categories in Census 2010.

Small communities that are losing population and/or have an imbalanced age-sex structure may be at risk of disappearing. Elsewhere in the state, some of the smallest communities could disappear. This is not new. In the 18th century, there were several hundred villages in the Aleutian Islands; by 1970, only 24 remained (Alonso and Rust 1976). Writing in the 1980s, Kruse and Foster (1986) noted that small communities were disappearing faster than new ones were forming. Table 5-1 and Figure 5-2 show population projections to 2025, and Figure 5-3 shows 2060 population projections. Future projections are calculated using the average annual rate of population change between 1990 to 2010. The most recent population data come from the US Census which was conducted in 2010.The base population in 2010 plus a one-year increase (calculated based on the annual average rate of change over the 20–year period between 1990 and 2010) equals the 2011 population[10]. In these communities, the population change over 20 years is smaller than the change from 2000 to 2010 and makes outlying values closer to zero. In general, nearer term population projections have less uncertainty than projections made further into the future; the 2025 projections are more reliable and plausible than the 2060 projections.

In expanding communities, population growth is limited by housing supply. Nearly all housing is funded by Housing and Urban Development (HUD) and the Bureau of Indian Affairs (BIA) and provided by regional housing authorities. Housing grants are provided to individual communities but are not large enough to build many houses at once. Most communities pool their grants through a regional housing authority and several houses are built at a time in each community on a rotating schedule.

Table 5-1. Community populations: current (2010) and 2025 projections.

Borough/Census Area	Place	Current (2010) Population	Projected (2025) Population	Direction of Change
Nome Census Area	Brevig Mission	388	793	+
	Elim	330	369	+
	Golovin	156	185	+
	Koyuk	332	420	+
	Nome	3598	3801	+
	Shaktoolik	251	302	+
	Shishmaref	563	565	+
	St. Michael	401	480	+
	Stebbins	556	575	+
	Teller	229	165	-
	Unalakleet	688	579	-
	Wales	145	131	-
	White Mountain	190	165	-
Northwest Arctic Borough	Ambler	258	177	-
	Buckland	416	438	+
	Deering	122	97	-
	Kiana	361	310	-
	Kotzebue	3201	3466	-
	Noorvik	668	745	-
	Selawik	829	963	-
	Shungnak	262	275	-
Wade Hampton Census Area	Marshall	414	593	-
	Mountain Village	813	950	-
	Pilot Station	568	608	-
	Pitkas Point	109	109	=
	Russian Mission	312	348	+
	St. Mary's	507	522	+
Yukon-Koyukuk Census Area	Anvik	85	56	-
	Grayling	194	194	=

[10] $Population_{t1}=Population_{t0}*(1+\text{rate of change})^{t1-t0}$

Borough/Census Area	Place	Current (2010) Population	Projected (2025) Population	Direction of Change
	Holy Cross	178	107	-
	Kaltag	190	127	-
	Koyukuk	96	86	-
	Nulato	264	159	-

Figure 5-2. Current (2010, left) and projected (2025, right) community populations.

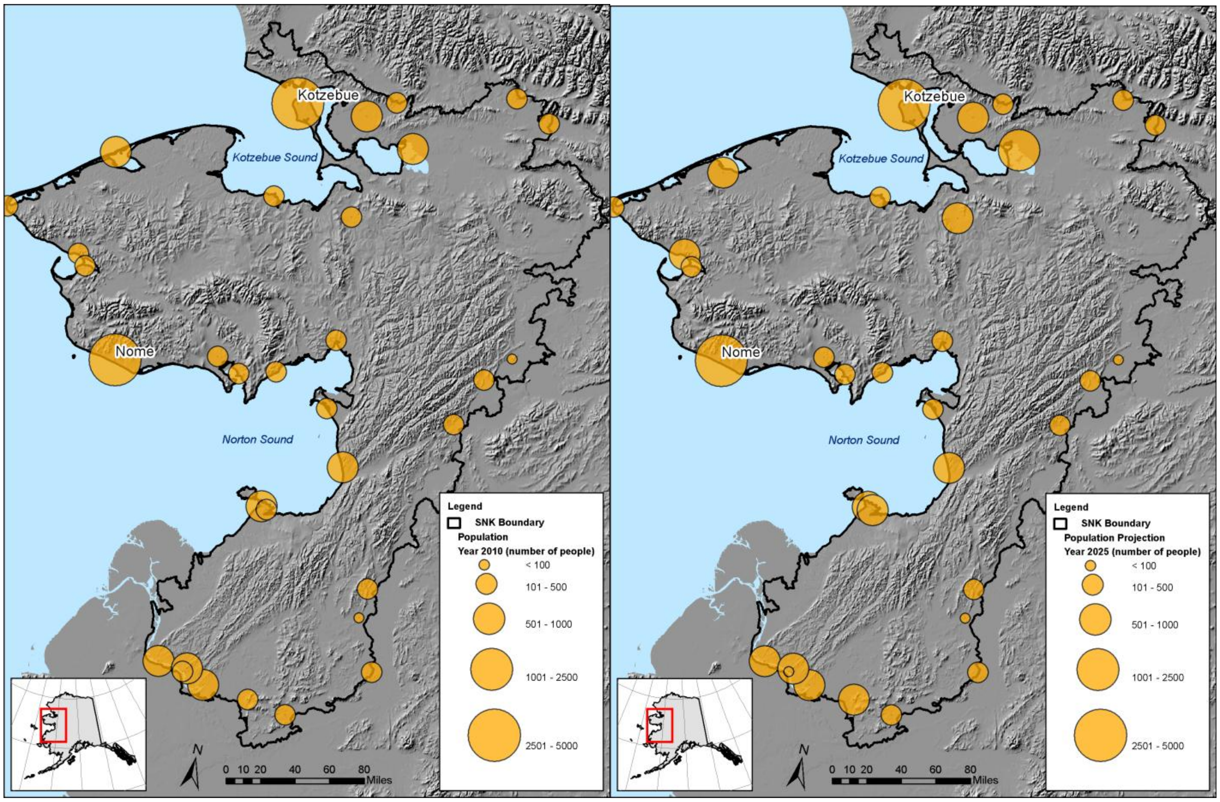
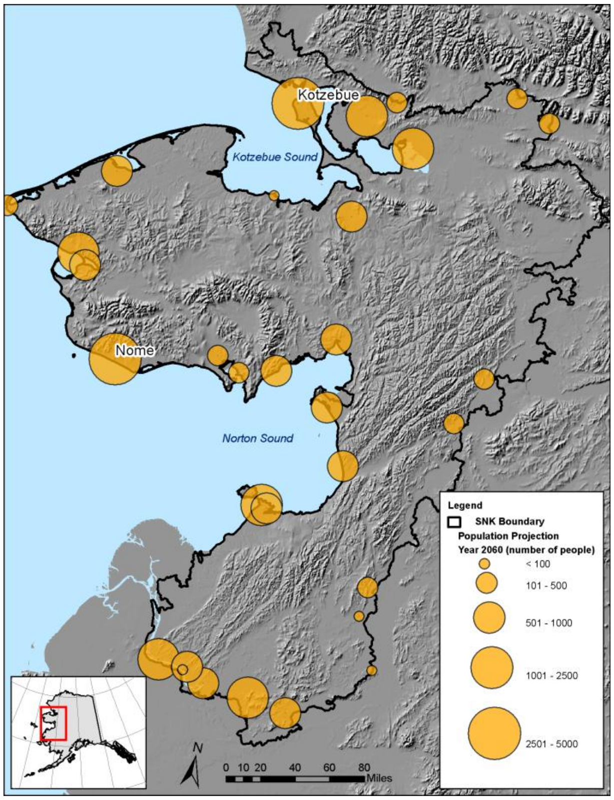


Figure 5-3. Community population: 2060 projections.Note that there is a much lower level of confidence associated with population projections for the more distant future.



5.1.2 Schools: Effect on Population and Employment

"An Alaska village fades when its school dies. That's because families with children often move when the school doors shut, sparking a downward spiral that can cost a village other services, such as regular mail deliveries or air travel" (Alaska Dispatch 4/10/12). When schools close[11], the remaining families with children usually move away, teachers who come from outside the community leave, many of the jobs supported by these people disappear. Besides fewer job opportunities, people remaining in the village have fewer family members and friends left for shared subsistence hunting and harvesting and other social activities. For people who remain, material and social well-being decline.

Within the SNK region, the school in Pitkas Point closed in 2012 because only eight students were enrolled. Because the community is connected to St. Mary's by road, students will ride the bus to St Mary's (Alaska Dispatch 2012). In most places, when schools close, the remaining families with school-age children move away. Besides Pitkas Point, two other communities in the region have small enrollments: Anvik and Koyokuk have enrollments of 20 and 14, respectively. By 2025, Deering and Holy Cross may also be at risk of losing their schools.

[11] Shutdowns began in 1999, after the legislature passed a law cutting off state funds for schools with nine or fewer students. Four years ago, the legislature passed another law to help ease the burden for districts with such schools. It phases out state support over four years, rather than ending funding abruptly (Alaska Dispatch 2012).

5.1.3 Wage Employment, Income, and Cost of Living

Communities will continue to rely on state and federal funding, at least in the near term. Employment data show slow job growth in regional centers and job loss in villages. Bering Straits Regional Corporation is in the process of purchasing Rock Creek/Big Hurrah mine and is considering developing Big Hurrah mine. Originally, when the project was owned by Nova Gold and encompassed two mines, Big Hurrah and Rock Creek, it was estimated to create about 110 local jobs (42 for Nome, and 69 for surrounding villages) and last 4-5 years. Ambler mining district could also add jobs but is not likely to be developed before 2025. A road would need to be built to access the mining district. The decision regarding a road to the mining district has become tied to a decision (led by Senator Mark Begich 2012) to build a deep water port in Arctic Alaska. The road to the mines would either go to the port, if the port location is in the northern part of the SNK ecoregion, or to the Dalton Highway.

The future looks expensive. Diesel fuel prices are expected to increase by $1.34 per gallon (over inflation) by 2025. Alaska renewable energy projects are currently funded under a state grant program. The Alaska legislature indicated in 2012 that it intends to continue to fund the program for the next 15 years at least. Renewable energy projects can help keep costs down but will not replace diesel generators, at least not in the near future. In places with renewable energy projects, conservation projects to recapture energy are the most common, followed by wind energy. Conservation projects are described by Alaska Energy Authority (AEA) as heat recovery projects, where heat generated in the production of electricity is used to heat nearby buildings. Wind contributes about 3% to community electricity supply. As the rural renewable energy fund expands, more communities in the ecoregion are adding wind generators. (Alaska Energy Statistics 2010).

5.1.4 Future Climate Change Effects on Communities

Climate change effects are producing the largest foreseeable economic changes. Shishmaref has voted to relocate and selected a new site. Shaktoolik, Selawik, Deering, Golovin, St. Michael and Unalakleet have all been identified by the Army Corps of Engineers as being at risk from erosion damage and will need to move or have major erosion projects in put place. Besides the enormous disruption to cultural traditions and place-specific knowledge, relocation projects require complicated government agency and community coordination. Cost estimates are $100-$400 million per community (USACE 2009, Brubaker 2011). Communities also find it difficult to find suitable new sites. Relocation, infrastructure replacement, and erosion protection needs come at a time when there is little federal funding. However, if funded, the relocation and erosion mitigation projects would be an economic boon for the region.

5.2 *Projected Subsistence Conditions*

5.2.1 Trends in Subsistence Harvests

This section addresses these management questions on how harvests have changed or are changing or could change due to a variety of factors. Additional detail is found in Appendix D.

6: Which species make up the largest share (lbs) of subsistence harvests? How is this changing?

4: How much have harvests (lbs.) changed over the past 20 years?

2: How could changes in sea mammal harvests potentially affect land-based hunting and fishing?

7: Given current and estimates of future subsistence species populations, are harvest regulations adequate to protect subsistence species populations?

44: How are transporters/tourism/sport hunt and fishing affecting the migration patterns of caribou?

Subsistence harvests are changing both because of changes in animal populations and because access to the animals is changing. Threats to sea mammal populations come from climate change and industrial development. Hunters are reporting fewer and less healthy animals (Ahmasuk et al. 2007). Offshore oil drilling and increased ocean traffic could adversely affect sea mammal health, populations, and migration patterns. Hunter travel has become more hazardous because sea ice is thinner and forms later in the year; lack of sufficient ice not only makes it more difficult to access animals but mistakes can lead to hunter death (Huntington and Fox 2005). Lack of shore ice and thin sea ice also means there is no space to haul out and butcher sea mammals.

The Western Arctic Caribou Herd (WACH) has decreased from 490,000 animals in 2004 to 325,000 in 2011 (Woodford 2012). The WACH working group[12] has been carefully monitoring the herd and is increasing the frequency of population counts of the herd as a first step in determining if, and what kind of hunting restrictions are appropriate. Rain-on-snow events in winter create a layer of ice that prevents caribou from accessing lichen; these events have increased in frequency and are expected to continue to increase with the changing climate. Late freeze-up slows caribou migration. When caribou can't cross rivers on thin ice, they may be forced to remain in less productive areas and be more vulnerable to predation (Huntington and Fox 2005). Caribou migrations have been later in the fall in the past few years. When the migration is in October, hunters can't reach the animals because of unstable and thin ice. With November migrations, hunters can travel on the ice but males are in rut and hunters have been taking more cows (personal conversation with Jim Magdanz, ADFG). Even though subsistence harvest is higher than sport hunter harvests – between 14,000 and 16,000 animals per year for subsistence compared to 800 for sport harvest – the numbers of sport hunters and subsistence hunters are approximately the same. This might mean that access to animals is difficult for subsistence hunters.

Subsistence hunters report that sport hunters shoot lead animals in the herd, disrupting the herd and scattering it. Aircraft noise from summer viewers and photographers could also be adding to stress and energy loss to caribou already are harassed by insects, at a time when they should be feeding and gaining fat reserves for the winter months (WACH Working Group 2003).

[1212] The group includes subsistence users, other Alaskan hunters, reindeer herders, hunting guides, transporters, conservationists, biologists, and natural resource managers.

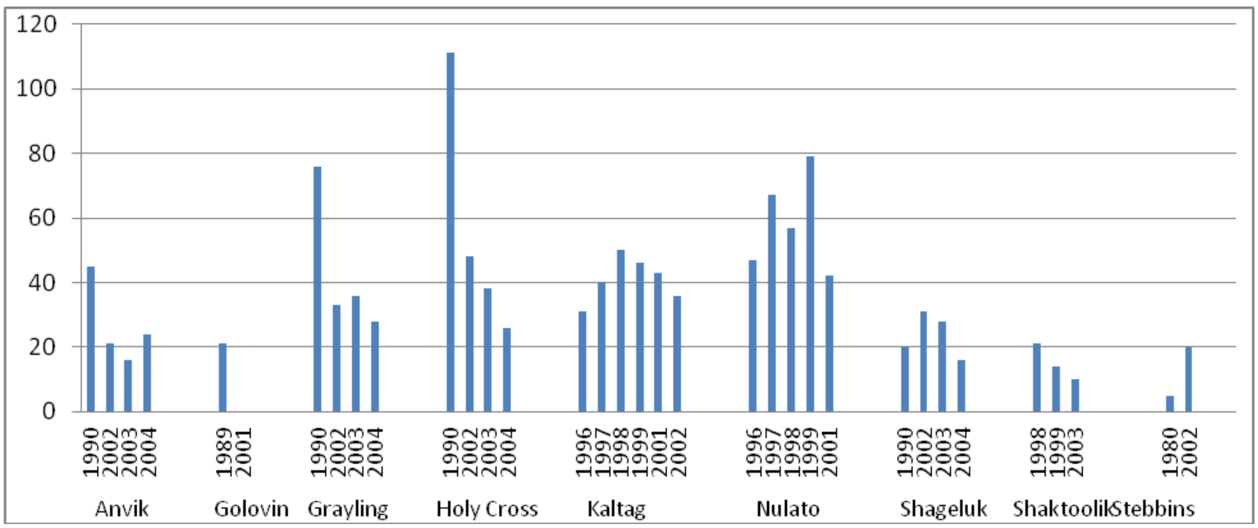
Weak salmon runs on the Yukon River have closed commercial fisheries and decreased subsistence harvests. Most subsistence fishermen also fish commercially. Without income from commercial fishing, they are left without enough cash for boat fuel and to repair equipment for subsistence fishing.

Changes in rivers and lakes make it difficult for boats to reach traditional caribou and moose harvest areas. Traditional hunting areas are important ties to culture, land, and history. Loss of access is more than just loss of animals harvested; hunter identity is tied to place-specific knowledge of the land and animals and success harvesting animals (Fox 2002).

Data from harvest surveys indicate that harvests have been decreasing over the past 20+ years, both in terms of total pounds of edible meat and edible pounds per capita. During the late 1980s and early 1990s, per capita harvests ranged from 600-1,000 pounds per person. More recent surveys show about 450 pounds per person. Salmon harvest surveys show that subsistence salmon harvests have declined since the late 1990s (Magdanz et al. 2005, Wolfe and Scott 2010).

Figure 5-4 shows data on subsistence moose harvests; the data show that moose harvests were 2 to 3 times higher in 1990 than 2002, and from 2000 to 2004 harvests dropped again by half. Holy Cross dropped from 111 animals to 26.

Figure 5-4. Moose harvests reported in subsistence surveys



5.2.2 Potential Response to Anticipated Declines in Subsistence Resources

The complex and synergistic effects of projected climate change, decrease in permafrost, and altered fire regimes are expected to impact subsistence species populations. Elsewhere in this report, the potential for decline in caribou populations (Joly et al. 2011) or increase in moose populations are noted, but in general, specific, quantitative population projections are not available. Although the subsistence-related MQs don't directly state this, several collectively suggest the need to better understand how subsistence communities might respond in the event of changing harvest levels. Based on the assumption that at least some subsistence species are likely to experience substantial declines in the future in this ecoregion, an overview of possible responses is provided.

How households would respond in the event of a sharp decline in the availability of subsistence resources is a function of the availability of other species, cultural preference and norms about what is fit to eat, the cost of equipment, knowledge of animal habitat and behavior, knowledge of how to hunt, and how to navigate terrain and weather, as well as the distance to animals and the cost of fuel to reach them. Whether people would eat more store-bought foods or shift to harvesting other species in response to a decline in species that they typically harvest depends on food cost and availability, job opportunities, and income.

Martin (2010) showed that during the caribou crisis in the mid-1970s, people in Anaktuvuk Pass ate more store-bought foods as a response. Compensating for the loss of caribou harvests by replacing them with other large subsistence mammals was impractical because of the distance to other mammal habitats and lack of knowledge about hunting them. However, at that time jobs were plentiful, so people could afford to replace their subsistence harvest with store-bought foods.

Other research shows subsistence harvests shifting to other similar species in response to declines in the subsistence species that are typically used by communities. Following the crash in the salmon population, lower Yukon River communities increased their harvest of non-salmon fish (Brown et al. 2005). Communities in the northwest Arctic switched from sheep to caribou when caribou migration routes brought animals closer to communities (Georgette and Loon 1999).

Other responses to a shortage could be traveling or moving to a community with access to animals, moving out of the region, increased harvests by communities with better access to those animals, along with increased sharing among communities. Currently and in the future, hunting rules and the degree to which they are enforced will also affect household responses. If hunting is more restricted and rules are strictly enforced, people are more likely to use other measures, like store-bought foods as replacement for subsistence harvested foods.

5.3 Change Agent Distribution and Intensity

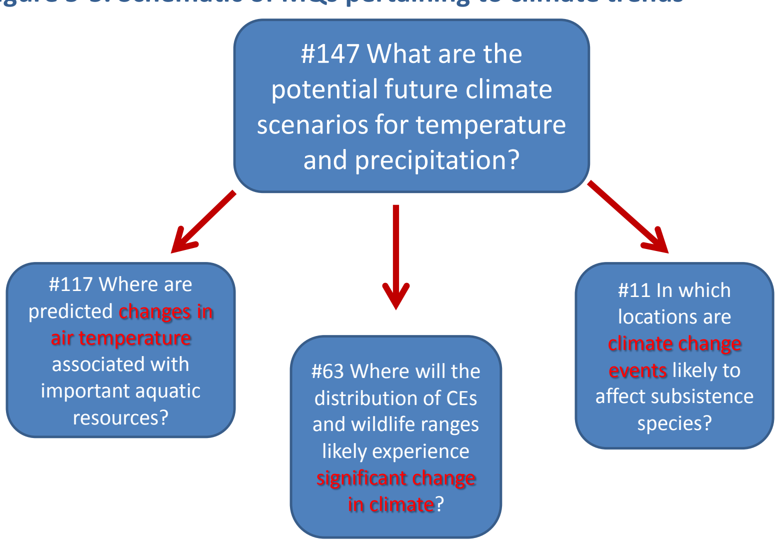
5.3.1 Climate Change

5.3.1.1 Climate Trends: Temperature and Precipitation, 2020s, 2050s, and 2060s

147: What are the potential future climate scenarios for temperature and precipitation?

The management questions displayed in Figure 5-5 all pertain to climate change. The primary question of “What are the potential future climate scenarios for temperature and precipitation?” is addressed in this chapter, while 117 and 11 are addressed in Appendix D, and 63 is addressed in the **Bioclimate Envelopes: Conservation Elements** section of this chapter as well as in Appendix B.

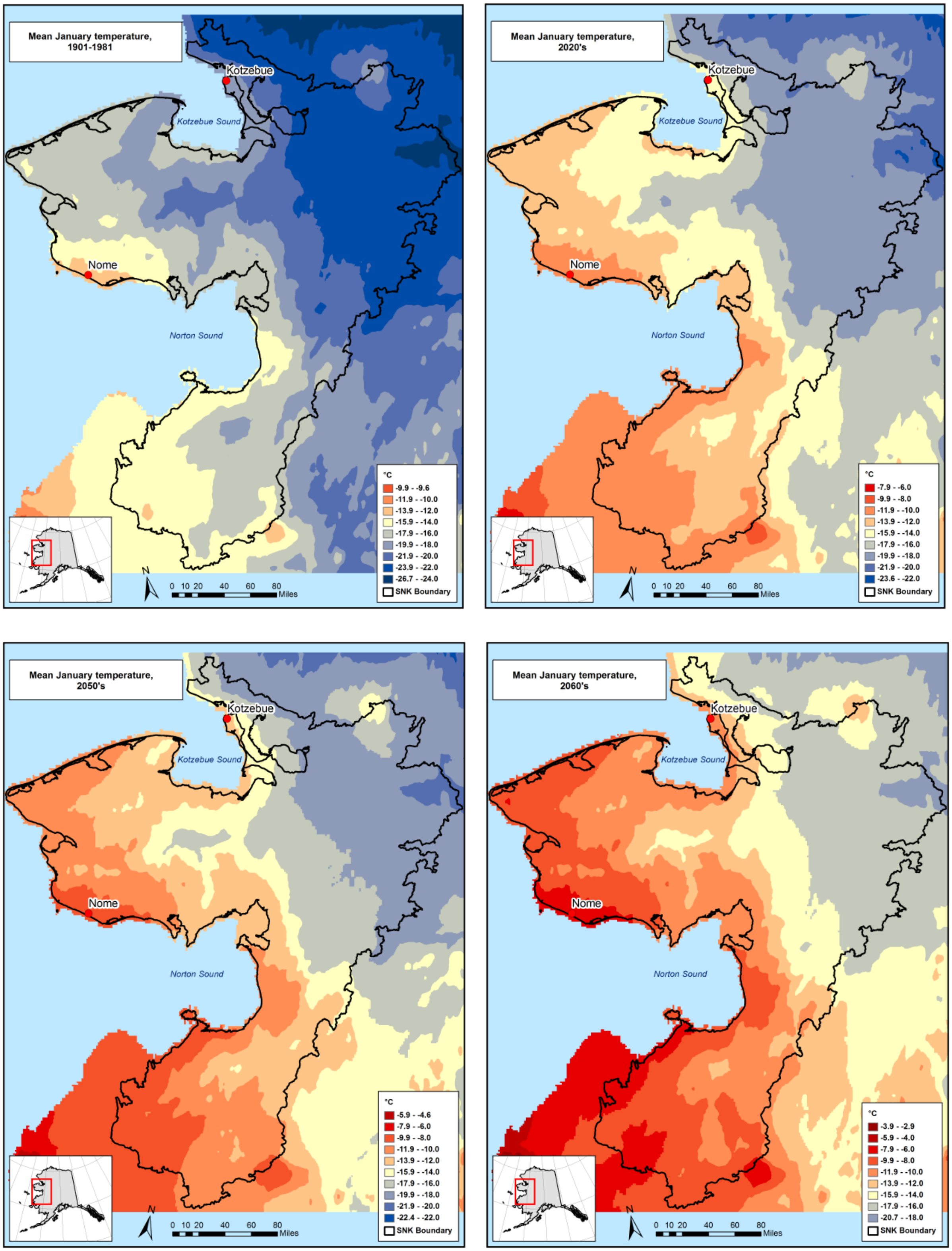
Figure 5-5. Schematic of MQs pertaining to climate trends



Analyses of SNAP climate projections for both the near future (2020s) and more distant future (2050s and 2060s) show a marked warming trend for all seasons, as compared to the baseline period (1901-1980). Data also indicates an increase in precipitation in future decades, although the certainty associated with this change is lower, in part due to greater natural variability in precipitation.

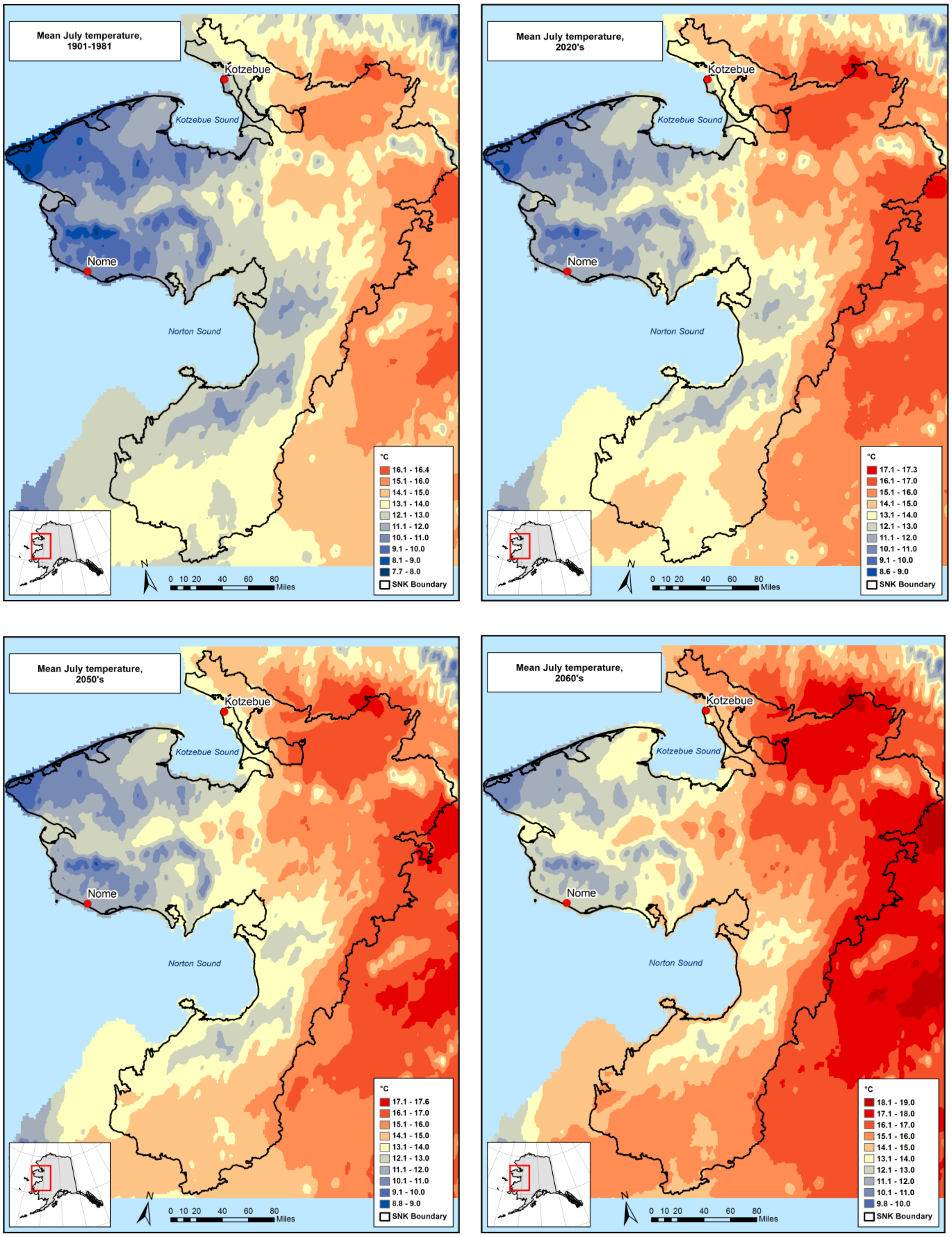
By 2025, January temperatures (Figure 5-6) are expected to increase by approximately 2°C in coastal areas and by approximately 3°C in upland and inland areas. By 2060, winter temperature shift is likely to become more profound, with regional increases of up to 8°C, and increases of at least 6°C in all areas.

Figure 5-6. January temperature for historical baseline (1901-1981) and three future decades (2020s, 2050s, 2060s).



Similar, although slightly less extreme changes are expected in summer conditions. Compared to historical conditions, July temperatures are expected to increase by approximately 1°C by 2025, and by about 2-3°C by the 2050s and 2060s (Figure 5-7).

Figure 5-7. July temperature for historical baseline (1901-1981) and three future decades (2020s, 2050s, 2060s).



Precipitation shifts are shown in Figure 5-8 (January) and Figure 5-9 (July). Overall precipitation patterns remain consistent across all seasons and time periods, and changes are relatively subtle, with slightly more precipitation expected throughout the SNK ecoregion. However, warmer temperatures may mean that less of this precipitation falls as snow during the shoulder seasons. Furthermore, warming and associated increases in evapotranspiration may more than offset increases in precipitation, leading to an overall drying effect. This is likely to have complex interactions with hydrologic changes associated with permafrost thaw (see Permafrost section).

Figure 5-8. January precipitation for historical baseline (1901-1981) and three future decades (2020s, 2050s, 2060s).

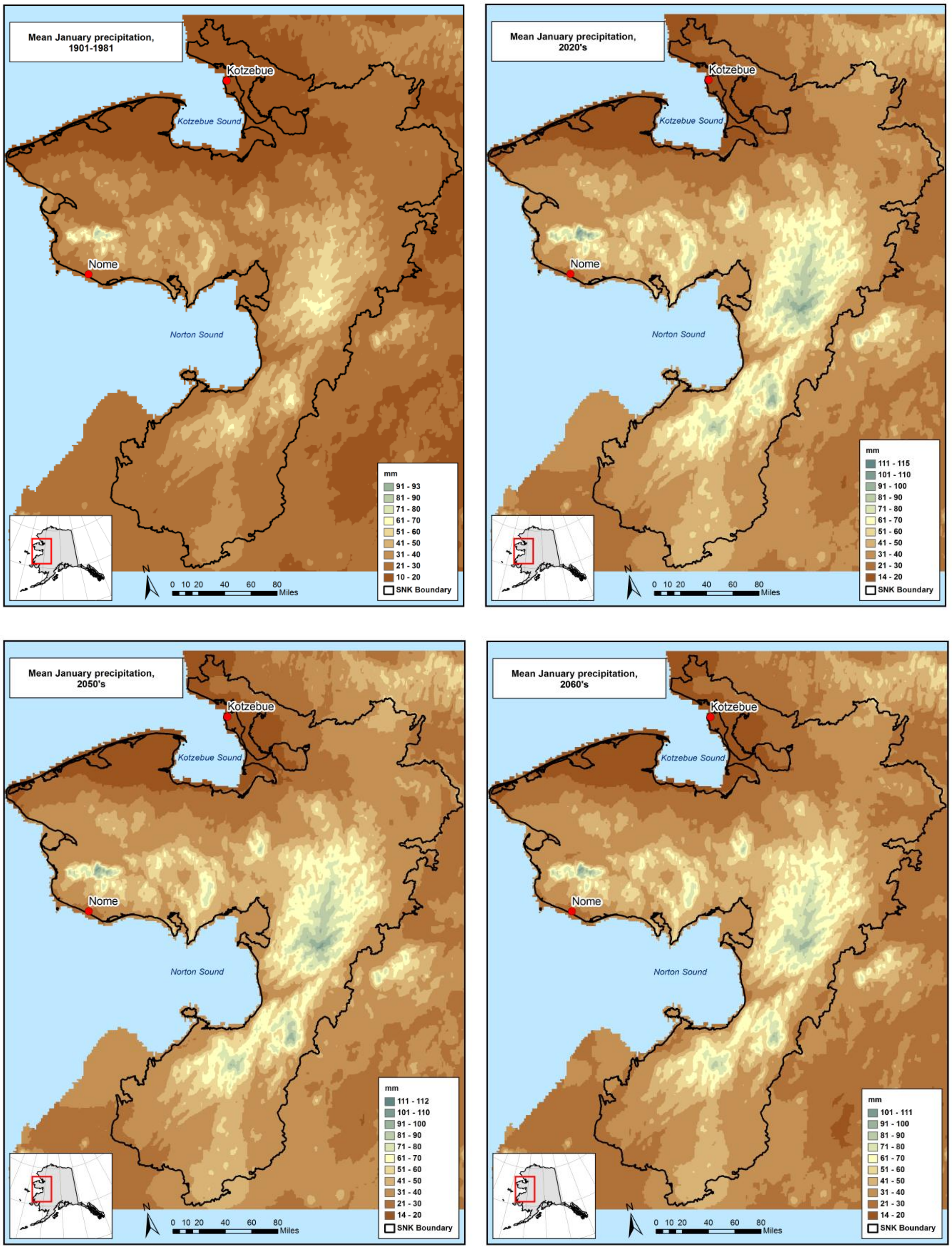
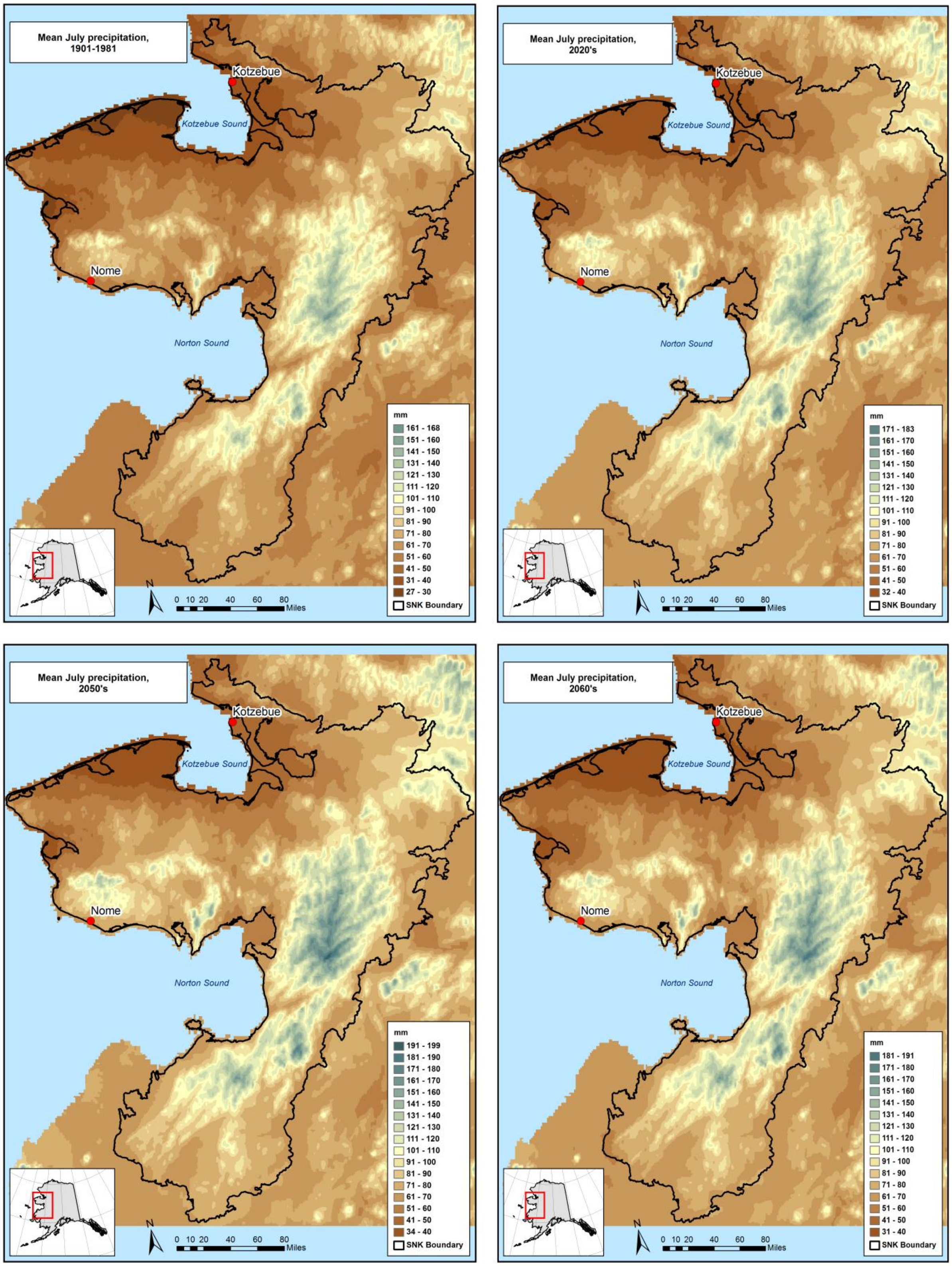


Figure 5-9. July precipitation for historical baseline (1901-1981) and three future decades (2020s, 2050s, 2060s).



Since climate varies considerably across the SNK ecoregion as a whole, due to differences in topography, latitude, and coastal influences, SNAP also assessed potential climate shifts on a "subecoregional" basis, shown in Table 5-2 (temperature) and Table 5-3 (precipitation). Of the six ecoregions examined, the Yukon-Kuskokwim Delta experienced the warmest mean annual historical temperatures (-2.4°C) and the Upper Kobuk-Koyukuk experienced the coolest (-5.7°C). However, monthly breakdowns reveal that the discrepancy between regions has historically been greatest in winter months, and that the temperature differences between regions vary seasonally. The Upper Kobuk-Koyukuk is the second-warmest area in July, and the coolest summers occur on the Seward Peninsula. In April, conditions are warmest in the Yukon River Lowlands and coldest in the Kotzebue Sound Lowlands.

Future projections show consistent temperature increases across all regions, meaning that the overall relationship among regions remains consistent. Mean annual temperatures are expected to increase by approximately 1.3°C between the historical baseline and the 2020s, and by about 2.5°C by the 2060s. However, this change is not evenly distributed month by month. Warming of six or more degrees Celsius is predicted in the winter months, whereas the spring, summer, and fall seasons are only expected to warm by 1-3°C.

Changes in precipitation also demonstrate a fairly steady pattern across the landscape. Of the six ecoregions examined, the driest historically is the Kotzebue Sound Lowlands, with approximately 321mm of rainfall equivalent annually. This is expected to increase to 362mm by the 2020s, and about 395mm by the 2060s. As previously noted, increases in precipitation may be offset with temperature-induced increases in evapotranspiration. The wettest region is the Nulato Hills, which is expected to increase from about 548 to about 678 mm annually.

As with temperature, seasonal patterns of precipitation vary from region to region.

Table 5-2: Historical and projected temperature (°C) by month, time period, and ecoregion

Kotzebue Sound Lowlands	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	MEAN
1901-1981	-20.3	-20.4	-17.9	-8.9	2.3	9.6	13.0	10.5	4.9	-5.2	-13.9	-19.3	-5.5
2020-2029	-16.9	-19.3	-15.1	-8.3	3.6	10.5	14.0	11.6	5.7	-3.8	-11.5	-15.0	-4.0
2050-2059	-15.7	-17.3	-14.4	-7.3	3.7	10.6	14.2	11.9	7.0	-1.8	-9.3	-13.2	-2.9
2060-2069	-13.6	-15.1	-13.9	-6.7	4.3	11.2	15.1	13.0	7.3	-1.5	-7.7	-12.9	-2.0
Nulato Hills	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**MEAN**
1901-1981	-19.0	-18.2	-13.3	-4.6	5.0	11.0	13.0	10.9	5.6	-4.5	-12.7	-18.7	-3.8
2020-2029	-15.5	-16.8	-10.3	-4.0	6.0	11.7	13.8	12.1	6.2	-3.4	-10.6	-14.4	-1.9
2050-2059	-14.3	-15.1	-9.6	-2.9	6.4	11.9	14.3	12.4	7.6	-1.6	-9.0	-13.2	-0.9
2060-2069	-12.7	-12.7	-9.2	-2.1	6.9	12.3	15.1	13.6	7.8	-1.3	-7.5	-13.3	0.0
Seward Peninsula	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**MEAN**
1901-1981	-18.2	-19.3	-16.6	-8.4	1.5	8.4	11.3	9.8	5.0	-4.1	-11.6	-18.6	-5.1
2020-2029	-14.9	-18.2	-13.6	-7.9	2.7	9.2	12.2	10.9	5.6	-2.8	-9.1	-14.0	-3.3
2050-2059	-13.5	-16.1	-13.0	-7.0	2.8	9.3	12.5	11.2	6.9	-1.0	-7.2	-12.3	-2.3
2060-2069	-11.5	-14.0	-12.3	-6.1	3.4	9.9	13.5	12.3	7.2	-0.7	-5.7	-12.0	-1.3
Upper Kobuk - Koyukuk	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**MEAN**
1901-1981	-22.7	-21.7	-18.0	-7.6	4.7	12.6	14.7	10.9	4.2	-7.4	-16.9	-21.6	-5.7
2020-2029	-19.4	-20.5	-15.6	-7.2	6.3	13.6	15.6	12.0	4.8	-6.1	-14.8	-17.8	-3.5
2050-2059	-18.5	-18.6	-14.8	-6.1	6.3	13.7	15.9	12.3	6.2	-4.0	-12.8	-16.3	-2.3
2060-2069	-16.6	-16.5	-14.5	-5.6	6.9	14.2	16.7	13.5	6.5	-3.7	-11.2	-16.2	-1.5
Yukon River Lowlands	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**MEAN**
1901-1981	-20.0	-18.7	-13.6	-4.1	6.3	12.9	14.8	12.3	6.7	-3.9	-13.1	-19.7	-3.3
2020-2029	-16.5	-17.3	-10.9	-3.6	7.5	13.6	15.6	13.5	7.2	-2.8	-11.2	-15.8	-1.9
2050-2059	-15.5	-15.6	-10.0	-2.6	7.8	13.8	16.0	13.9	8.6	-1.0	-9.8	-14.7	-0.9
2060-2069	-14.0	-13.3	-9.7	-1.8	8.3	14.2	16.9	15.0	8.9	-0.8	-8.2	-14.7	0.0
Yukon - Kuskokwim Delta	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**MEAN**
1901-1981	-15.5	-15.7	-11.7	-5.2	4.3	10.6	12.9	11.7	7.0	-2.0	-9.2	-15.5	-2.4
2020-2029	-11.8	-14.4	-8.3	-4.5	5.2	11.2	13.7	12.8	7.6	-1.0	-7.0	-11.0	-0.9
2050-2059	-10.4	-12.5	-7.7	-3.5	5.6	11.4	14.1	13.1	8.9	0.7	-5.5	-9.8	0.1
2060-2069	-8.9	-10.0	-7.1	-2.4	6.1	11.9	15.0	14.3	9.2	1.0	-4.0	-9.8	1.0

Table 5-3: Historical and projected precipitation (mm) by month, time period, and ecoregion.

Kotzebue Sound Lowlands	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	TOTAL
1901-1981	16.9	15.6	14.0	14.4	14.2	19.1	45.4	64.9	53.5	27.8	17.0	17.9	321
2020-2029	23.1	15.9	18.6	17.6	14.1	20.0	48.7	73.0	56.0	28.9	18.9	27.3	362
2050-2059	23.3	20.2	20.7	18.8	16.6	23.7	53.8	72.9	63.3	35.0	20.3	24.3	393
2060-2069	23.0	19.5	17.2	20.2	17.5	23.8	51.1	74.1	71.1	34.4	21.6	23.1	397
Nulato Hills	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**TOTAL**
1901-1981	36.8	31.8	24.1	16.3	27.2	36.0	90.2	101.2	70.5	49.8	35.2	28.6	548
2020-2029	53.1	34.2	32.1	18.8	27.9	40.0	97.8	114.7	74.6	51.9	41.4	43.4	630
2050-2059	52.3	42.0	35.3	20.6	31.2	44.4	105.9	122.1	86.3	61.2	42.8	36.9	681
2060-2069	50.1	41.4	29.6	22.7	35.6	45.6	102.6	116.0	91.8	61.2	46.1	35.5	678
Seward Peninsula	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**TOTAL**
1901-1981	30.1	25.3	21.7	18.8	16.0	25.6	59.4	84.5	69.4	36.5	27.6	24.4	439
2020-2029	39.4	24.9	28.5	22.3	16.8	29.3	66.1	95.3	72.3	37.8	30.7	36.0	499
2050-2059	39.0	31.3	31.2	23.9	17.8	33.9	72.3	96.4	82.3	44.6	32.1	30.9	536
2060-2069	38.9	31.6	26.0	25.0	20.7	33.6	68.1	97.9	87.7	44.2	34.2	29.6	537
Upper Kobuk-Koyukuk	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**TOTAL**
1901-1981	23.3	20.5	20.2	23.4	24.9	33.8	70.3	99.3	84.2	38.6	23.2	27.4	489
2020-2029	32.6	22.2	27.3	28.5	24.0	34.6	73.4	108.3	87.2	39.8	26.2	41.9	546
2050-2059	32.9	27.9	30.5	30.6	29.6	40.3	81.8	110.1	97.7	48.1	27.5	38.3	595
2060-2069	32.3	26.0	25.0	33.6	30.1	40.3	78.2	110.3	111.6	47.6	29.6	36.6	601
Yukon River Lowlands	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**TOTAL**
1901-1981	24.3	21.4	19.6	13.7	19.6	30.6	61.3	78.8	55.7	35.4	25.5	22.5	408
2020-2029	35.0	23.7	25.5	15.8	20.1	32.6	65.6	88.2	58.3	37.0	29.8	34.2	466
2050-2059	34.8	28.8	28.4	17.2	22.8	36.5	71.8	94.5	67.3	42.8	30.8	29.4	505
2060-2069	32.6	28.0	23.9	19.4	25.4	37.1	69.4	88.1	71.7	43.0	33.1	28.6	500
Yukon-Kuskokwim Delta	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**TOTAL**
1901-1981	25.9	19.2	22.8	17.4	19.6	29.7	58.9	84.7	63.7	39.0	32.3	28.2	441
2020-2029	35.9	20.4	30.5	19.1	20.9	36.6	65.3	97.2	67.7	39.7	37.7	41.3	512
2050-2059	35.0	24.9	32.4	21.0	22.3	39.6	69.5	105.5	78.4	46.4	38.5	34.7	548
2060-2069	34.4	25.1	28.0	22.9	26.5	41.4	67.1	98.1	81.3	46.0	41.3	33.5	546

It must of course be kept in mind that uncertainty is associated with all the above described data, as detailed in the previous sections. In order to address the MQs associated with climate change, in addition to providing data on total predicted change, a decision had to be made about how to assess what constituted "significant" change. The metric selected was number of standard deviations from mean baseline values, where the baseline is the historical time period 1901-1980. SNAP spatially analyzed each map pixel for every month of the selected future decades (2020s, 2050s, and 2060s) to determine how many standard deviations these decadal monthly mean values are from the baseline mean for each respective month for temperature and precipitation (Figure 5-10 through Figure 5-13). This approach was mathematically unconventional, since standard deviations for monthly means at annual time-steps are being compared to decadal monthly means, which have been smoothed by averaging. However, this method does create a useful metric for addressing the question of whether typical (average) future values are likely to be outside of the range of 66% (one standard deviation) or 95% (two standard deviations) of historical values. This study examined the upper ranges of "abnormal" conditions –that is, only unusually warm and unusually wet months, not unusually dry or cold months; therefore, the actual expected occurrences of values outside two standard deviations would be only approximately 2.5%, representing the upper tail of the bell-curve distribution. For example, in the 2050s or 2060s, will a typical June be hotter than 97.5% of all historical Junes?

Figure 5-10. Proportion of Januarys in the 2020s decade (left) and in the 2060s decade (right) with temperatures outside the historical (1901-1980) normal range.

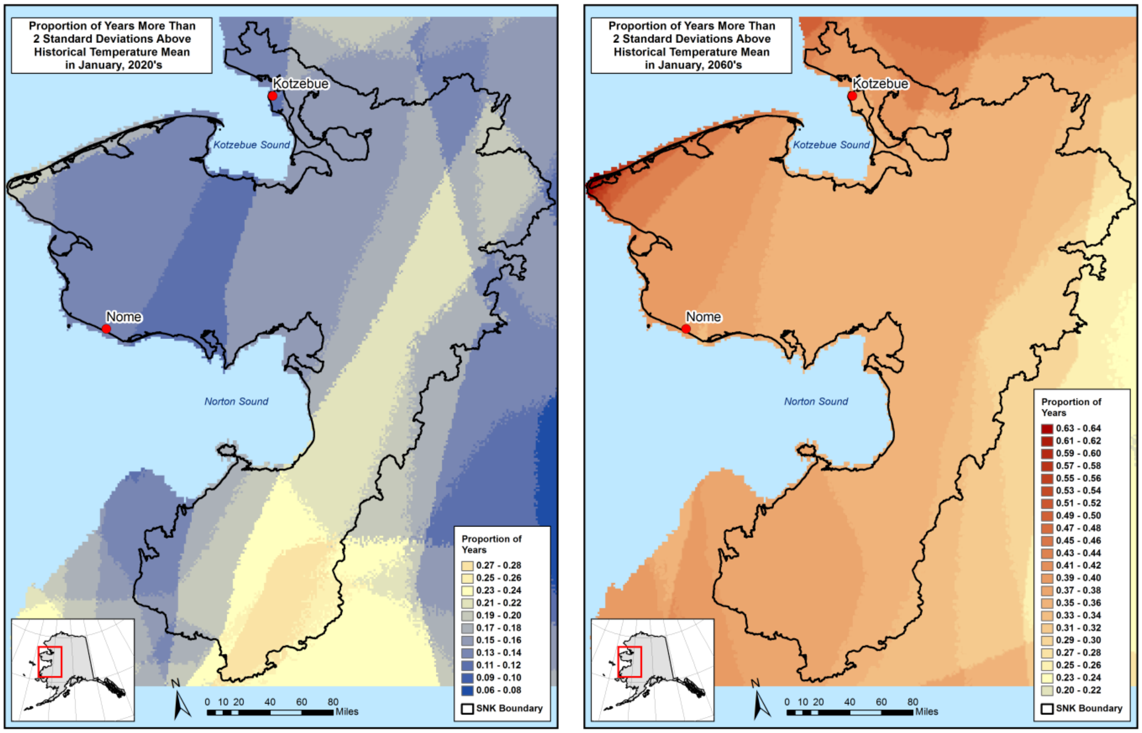


Figure 5-11. Proportion of Julys in the 2020s decade (left) and in the 2060s decade (right) with temperatures outside the historical (1901-1980) normal range.

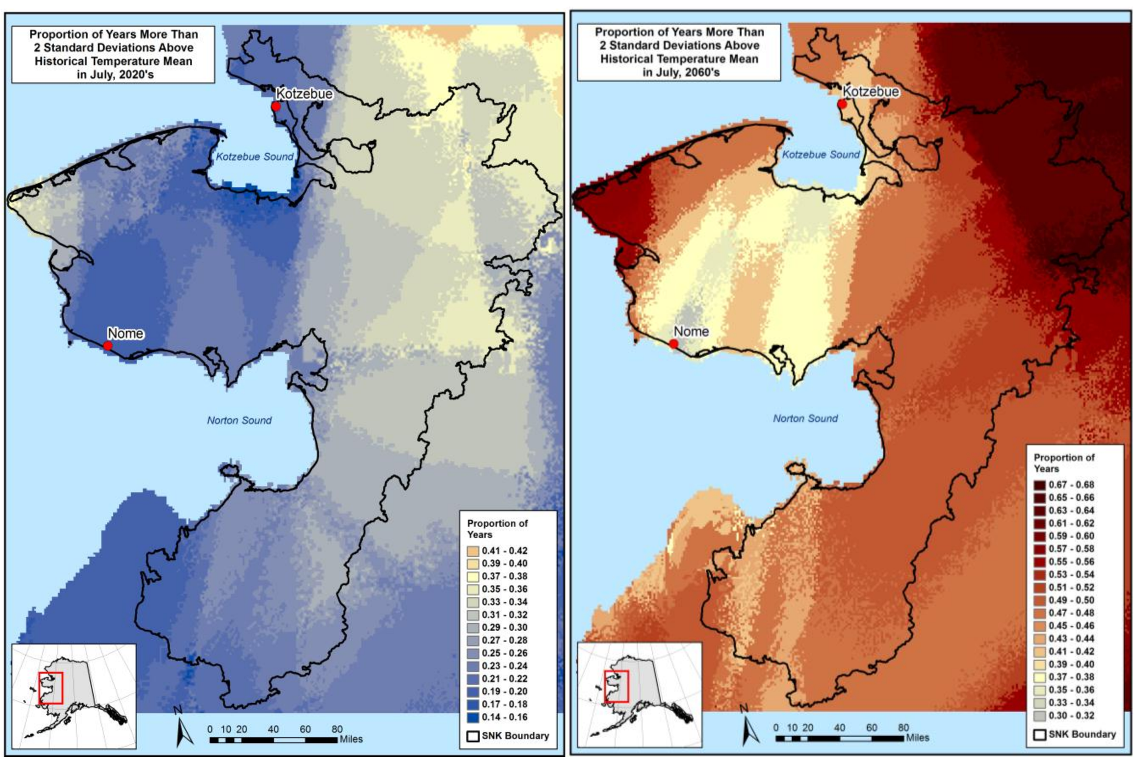


Figure 5-12. Proportion of Januarys in the 2020s decade (left) and in the 2060s decade (right) with precipitation above the historical (1901-1980) normal range.

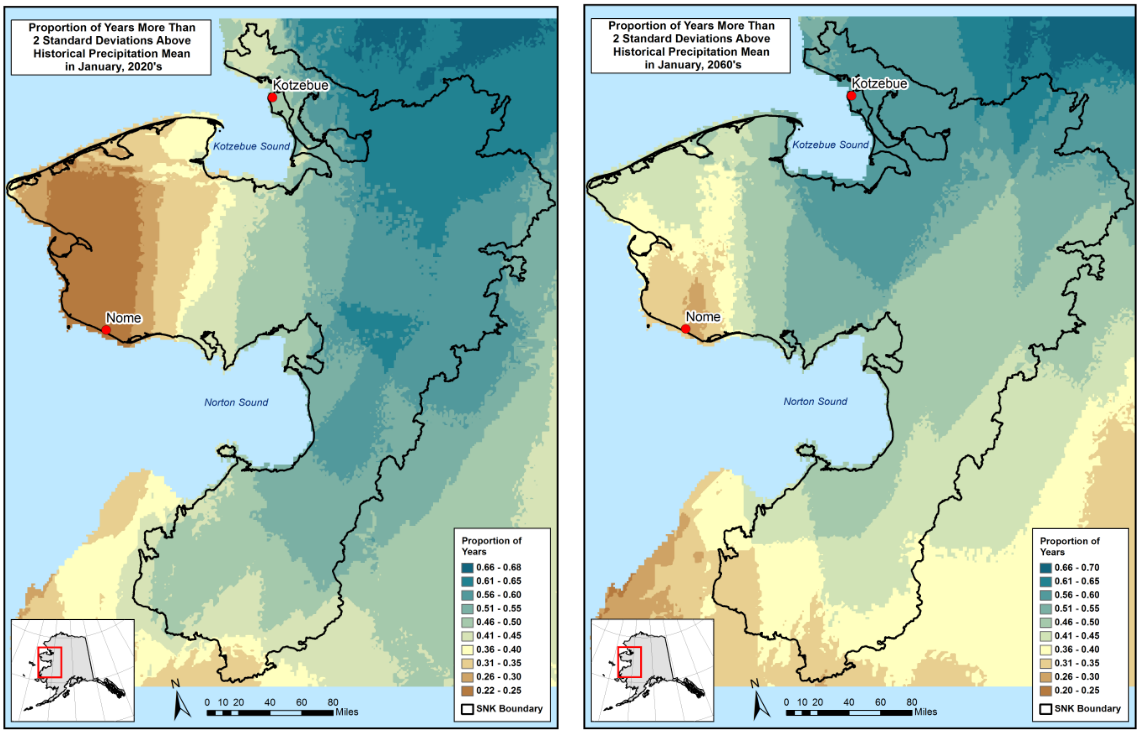
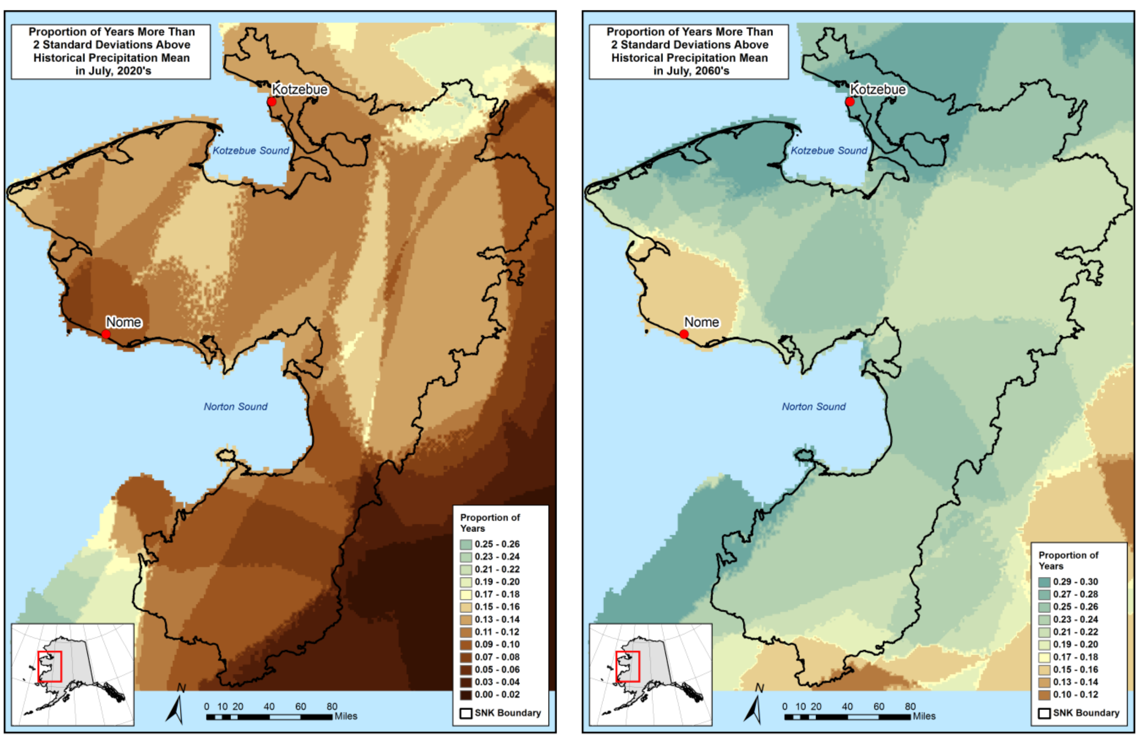


Figure 5-13: Proportion of Julys in the 2020s decade (left) and in the 2060s decade (right) with precipitation above the historical (1901-1980) normal range.



Results of this analysis show that while many projected mean values still fell within the "normal" range, especially over the relatively short time frame between the historical baseline and the 2025, far more values were "abnormal" than could be expected by mere chance. For example, by the 2060s, models predict that at least a quarter of Januaries will be abnormally warm across the entire study area, and that in the coastal regions of the Seward Peninsula, more than half of Januaries will be warmer than 97.5% of all historical Januaries.

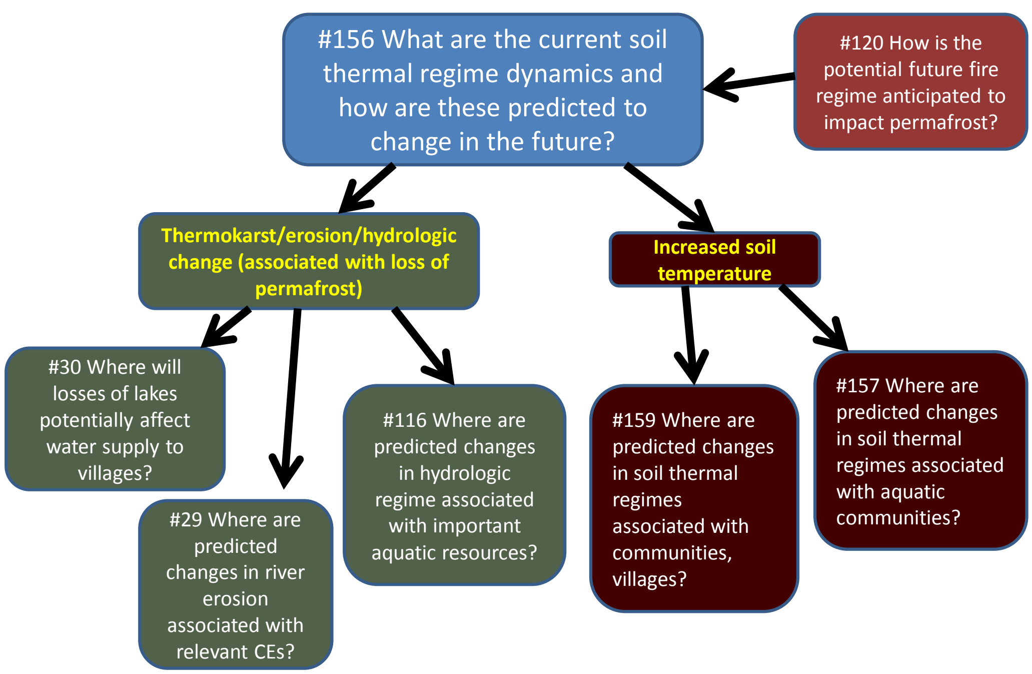
Results are even more marked for July temperatures. It is interesting to note that although overall temperature increases are expected to be greatest in the winter months, the proportion of months expected to be outside the normal range is greatest for the summer and fall. This is presumably due to lower historical variability in temperature during these months. However, for precipitation, results show the opposite pattern, with more "abnormal" months expected in the winter and spring as compared to the summer and fall.

Regionally, temperature patterns are expected to stray further from historical norms in inland regions, as compared to the coast. Likewise, precipitation is expected to be further from historical patterns in inland regions, again perhaps because of lower historical variability here, as compared to coastal areas.

5.3.1.2 Permafrost Trends: 2025 and 2060

The management questions illustrated in Figure 5-14 are linked to climate-induced changes in permafrost. The primary question to be addressed is "What are the current soil regime dynamics and how are these predicted to change in the future?" The modeling methods and results described below provide the direct answer to this management question. The other management questions are discussed in relevant portions of Appendix D, Other Assessments.

Figure 5-14: Schematic of MQs related to permafrost



156: What are the current soil thermal regime dynamics and how are these predicted to change in the future?

Permafrost is expected to undergo significant thaw across much of the REA (Figure 5-15) as mean annual ground temperature at one meter depth rises from below 0°C to above 0°C. Note that thaw at one meter does not equate with total permafrost loss, since deeper permafrost is likely to persist much longer, with a talik layer above it. In addition, areas that are already without permafrost are likely to experience shallower winter freezing, and areas that retain permafrost throughout the study period are likely to experience deeper summer thaw (thicker active layer) (Figure 5-16).

Figure 5-15. Modeled mean annual ground temperature (MAGT) at 1 m depth in 2011 (left), 2025 (center), and 2060 (right). All 240 ecoregional subunits (5th-level watersheds) are shown.

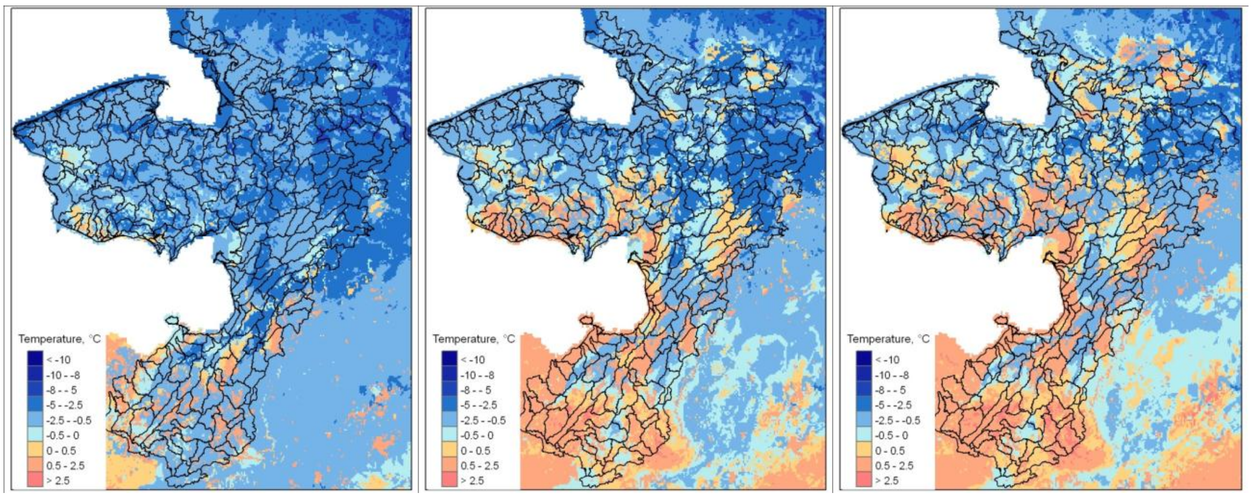
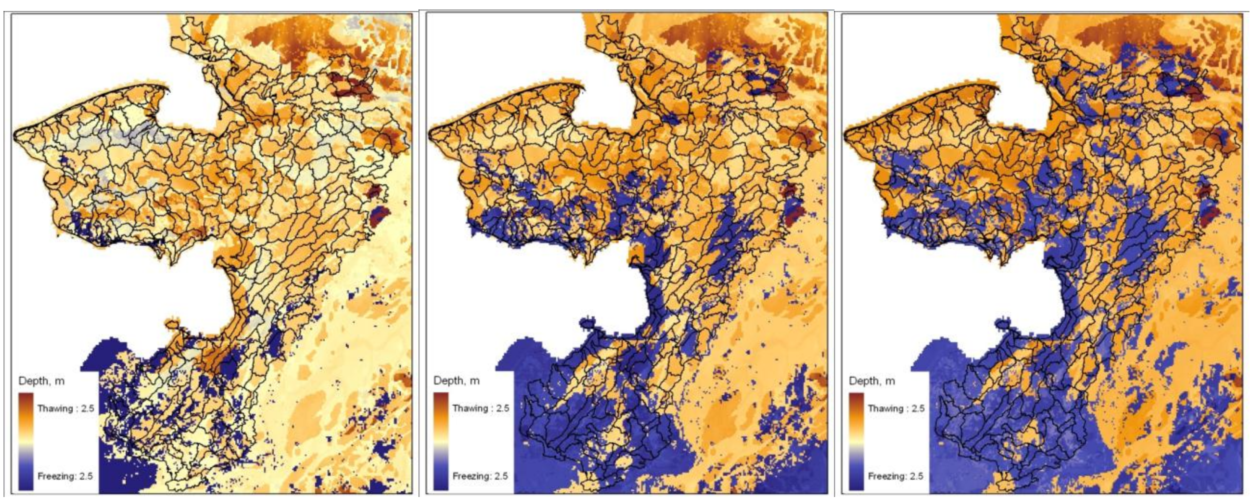


Figure 5-16. Modeled active layer thickness (yellow-brown) and depth of seasonal freezing (purple) in 2011 (left), 2025 (center), and 2060 (right). All 240 subunits (5th-level watersheds) are shown.



However, predictions are highly variable across the landscape. Due to model uncertainty, the model results should be viewed as indicators of potential change rather than as certainties. The REA includes a total of 240 5th level HUCs, totaling 145,620 square kilometers. HUCs range in size from 6 to 308 grid cells. Current (2011) MAGT by HUC ranges from -5°C to +1°C. There is high variability within HUCs, with standard deviations ranging from 0.08 to 2.3°C. In 2011, no HUCs were modeled with all grid cells thawed (Table 5-4), and 152 HUCs were estimated to be entirely underlain with permafrost. By 2060, model results show nine completely thawed HUCs and only 33 HUCs with no thaw. (Complete results by HUC are provided in the permafrost section in Appendix A.) Transition shifts (from below freezing to above freezing conditions at one meter depth) are indicated by changes in cell shading from blue to pink. These phase changes can be considered to be highly likely at the local level. However, they will not necessarily correspond with immediate or clearly predictable changes in hydrology and vegetation, due to the unpredictable lag times and drainage patterns associated with permafrost thaw.

Table 5-4. Summary of projected permafrost presence/absence by 5th-level watershed (10-digit HUC).

Year	Mean annual ground temperature (MAGT) at bottom of active layer	Number of HUCs with MAGT < 0°C	Number of HUCs with no grid cells **above** freezing	Number of HUCs with no grid cells **below** freezing	Approximate percentage of total area with MAGT > 0°C
2011	-1.84	231	152	0	5%
2025	-0.90	188	75	4	23%
2060	-0.48	171	33	9	30%

Implications for land management are complex, since permafrost degradation leads to substantial hydrologic and vegetative changes. A recent study of the effects of changes in active layer thickness and soil drainage on vegetation distribution near the Arctic treeline on the Seward Peninsula (Lloyd et al. 2003) showed successful establishment of trees and shrubs at thaw-pond sites where permafrost degradation had occurred. Thus, permafrost thaw may accelerate shrubification and drying of soils. Lloyd et al. (2003) stressed that these effects were particular to microsites, implying that managers must assess change on a case by case basis. Although it is likely that some lake drainage will occur as a direct result of permafrost loss, it is difficult to predict which ponds and lakes will be affected, or the timing of the change. See Appendix D for further discussion of MQs relating to the effects of changes in permafrost.

5.3.1.3 Bioclimate Envelopes: Conservation Elements

Bioclimate envelope models were selected at the beginning of the SNK REA process as the tool for understanding how areas of altered climate will relate to the distributions of CEs; they were developed to address this management question on CE distributions and climate change.

> **63**: Where will the distribution of CEs and wildlife ranges likely experience significant change in climate?

Another pair of management questions relate to climate change and species. Considering climate change as a whole, the bioclimate envelope models indicate where altered climate has the potential to affect subsistence species (MQ 11), by illustrating how the climate envelope will shift in the future. Predicting areas with increased risk of specific climate-change related weather events, such as rain-on-snow, or more frequent coastal storms, is not possible with available data and modeling tools. These possibilities are further qualitatively discussed in Appendix D, in the section on **Climate Trends and CEs**. The caribou habitat-related MQ is informed by the bioclimate envelope results for caribou winter range provided in this section and is also further qualitatively discussed in the section **Climate Trends and CEs** in Appendix D.

> **11**: In which locations are climate change events likely to affect subsistence species?
>
> **103**: Will suitable habitat for caribou be available with climate change?

In order to forecast how climate change may result in geographic shifts of the suitable climatic conditions for a species, its 'bioclimatic envelope' must first be defined. A bioclimatic envelope describes the range of climatic conditions within which a given species occurs, and the variables used to define it are determined by the spatial climate data available for the region of focus. Species distribution models, also called ecological niche models, can be used to identify a species bioclimatic envelope by correlating known localities of that species' current range with current climatic conditions to generate a species' multidimensional bioclimatic 'envelope' or 'niche'. The species' identified n-dimensional bioclimatic envelope can then be projected into 21st century climate scenarios, resulting in a map of the future spatial extent of the species current bioclimatic niche. Of course, climactic conditions such as air temperature and precipitation levels are not the sole defining characteristics of species occupied range. It is important to understand that for a given species these models are specifically looking at suitable bioclimate, not suitable habitat or potential range. Nonetheless, climatic conditions play a broad role in determining the suitability of habitat for most species, and they have indirect influence on those other factors, such as the extent of certain vegetation communities or the characteristics of local hydrology, that in turn influence habitat selection for species. Thus, this information can serve as one of many inputs in developing an understanding of how climate change might affect a given species of management interest, and offers a basic building block for a myriad of studies that include vulnerability assessment, prediction of extinction risk, analysis of future conservation priorities, and species range shifts.

The species distribution modeling algorithm MaxEnt (Phillips et al. 2006, Phillips and Dudik 2008) was used in conjunction with spatial climate data from SNAP to model current and future bioclimate of conservation elements in the SNK region. Maxent is a correlative niche model that uses the principle of maximum entropy to estimate a set of functions that relate environmental variables and species known occurrences in order to approximate species' niche and potential geographic distribution. Maxent was chosen because of its established performance with presence-only data relative to alternative niche modeling techniques, and its built-in capacity to deal with multi-colinearity in the environmental variables (Elith et al. 2006, Elith and Leathwick 2009). Maxent focuses on how the environment where the species is known to occur relates to the environment across the rest of the study area (the "background"). The model does not identify either the species occupied niche or fundamental niche; rather the model identifies only that part of the niche defined by the observed records (Phillips et al. 2006, Elith et al. 2011).

Niche models were generated using the CRU 2km^2 (1901-1981) monthly data to define the current niche of a species, which was then used to estimate future range shifts using the SNAP climate projections of downscaled spatial climate surfaces from 5 different GCMs (see section A-4.1 for further details on SNAP spatial climate data). The five GCMs used for this study were selected by SNAP because they perform the best in a historical re-analysis of climate conditions in the Alaska and the Arctic. Using multiple GCMs allows an assessment of the degree of agreement across a range of global climate models, thereby offering an assessment of uncertainty. Two time slices were explored: 2020s (2020-2029) and 2050s (2050-2059). These three datasets offer a time series from 20th century baseline to mid 21st century of projected changes in monthly average temperature and monthly total precipitation.

The species distribution modeling algorithm MaxEnt (Phillips et al. 2006, Phillips and Dudik 2008) was used in conjunction with the historical CRU dataset and the SNAP Climate Projections (both at 2km resolution) to model current and future bioclimate of conservation elements in the SNK region. Each time slice (2020s and 2050s) was run independently with each of 5 different GCMs. The probability outputs were then converted to presence absence and then combined using an additive function. Adding all model outputs creates a single layer of future suitable bioclimate with values of 1-5 representing climate model agreement. Therefore, each time slice for a given species has 5 possible values, with 5 being the highest level of agreement (all 5 GCMs agree on a species predicted suitable bioclimate in a given pixel) and 1 being the lowest, (only 1 GCM predicts suitable bioclimate in a given pixel). This approach supports an assessment of multi-model agreement in projections of bioclimatic shifts. While all of these ensemble layers were included as deliverables to the BLM, we use change summary maps in the report for displaying results. See B-2.3.1.3 for an example of an ensemble layer.

Six species CEs received bioclimate envelope models. Selection of species for envelope modeling was guided by their importance as a species of management concern, the likelihood of climate as at least a partial driver of their distributions, the available distribution data, and the spatial extent of available downscaled future climate data. Table 5-5 lists the species for which bioclimate envelope models were produced. Climate data and species locality data were not readily available for areas outside of Alaska; therefore, more wide-ranging species CEs could not be adequately modeled. Because caribou is a widely distributed species, and the interest for the SNK ecoregion is on the Western Arctic Herd, climate envelope models were developed for two specific habitat components of the WAH: winter range and calving grounds.

Table 5-5. Species CEs and invasive species CAs chosen for bioclimate envelope modeling with model parameters. Months listed are associated with the climate variables monthly maximum temperature, minimum temperature, and total precipitation. Baseline climate data is used to define the current climate envelope for a species.

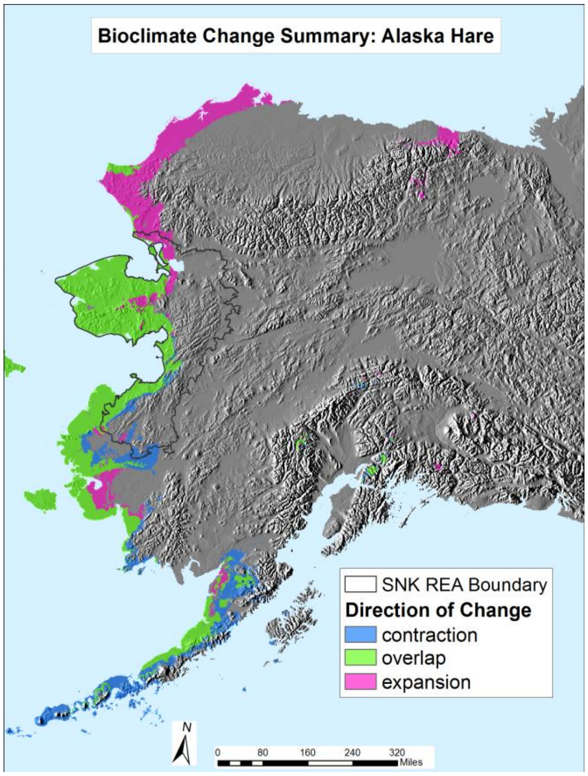
CEs/CAs	Species	Months	Baseline	Future Time Slices
Mammals CE	Alaskan hare	1-12	1901-1981	2020s, 2050s
Birds	Arctic peregrine falcon	6,7,8	1901-1981	2020s, 2050s
	Hudsonian godwit	6,7,8	1901-1981	2020s, 2050s
	Bristle-thighed curlew	6,7,8	1901-1981	2020s, 2050s
	Bar-tailed godwit	6,7,8	1901-1981	2020s, 2050s

CEs/CAs	Species	Months	Baseline	Future Time Slices
Subsistence	Western Arctic Caribou: winter range	10,11,12,1,2,3,4	1991-2009	2020s, 2050s
Invasive CAs	White sweet clover	1-12	1901-1981	2020s, 2050s
	Orange hawkweed	1-12	1901-1981	2020s, 2050s

5.3.1.3.1 Mammals

Management questions relating to the impact of climate change on conservation elements were addressed in part by assessing the difference between modeled bioclimatic distributions for current climate conditions, and climate conditions projected from a suite of SNAP downscaled climate models for the 2020s and 2050s. Model projections were provided to BLM for the 2020s and 2050s, but tables and map summaries used the 2050s to measure change compared to current conditions. The bioclimate modeling section in Appendix B provides further detail on bioclimatic envelope methods and results. Figure 5-17 shows an example of a summary change map of the bioclimatic envelope shift for the Alaskan hare. For all summary change maps, at least two of the five GCMs agree on the modeled result for that pixel. Green areas indicate overlap between the modeled current bioclimate and the future projected distribution of this climatic envelope, indicating where bioclimate may be relatively stable and maintained in the future. The Alaskan hare is predicted to maintain most of its bioclimate within the SNK REA. Blue areas in the southern part of its range indicate areas where the future climate envelope has contracted from its current extent, suggesting a climate regime shift and potential impact on the Alaskan hare. Pink areas show where current climate conditions are projected by midcentury to occur outside the current modeled distribution. These results for the Alaskan hare show a potential for expansion of suitable bioclimate north of the REA. However, many other ecological and biotic factors must be considered besides future climate conditions when projecting where a species range might shift. These results are most useful in understanding which areas of the current bioclimate range may remain stable.

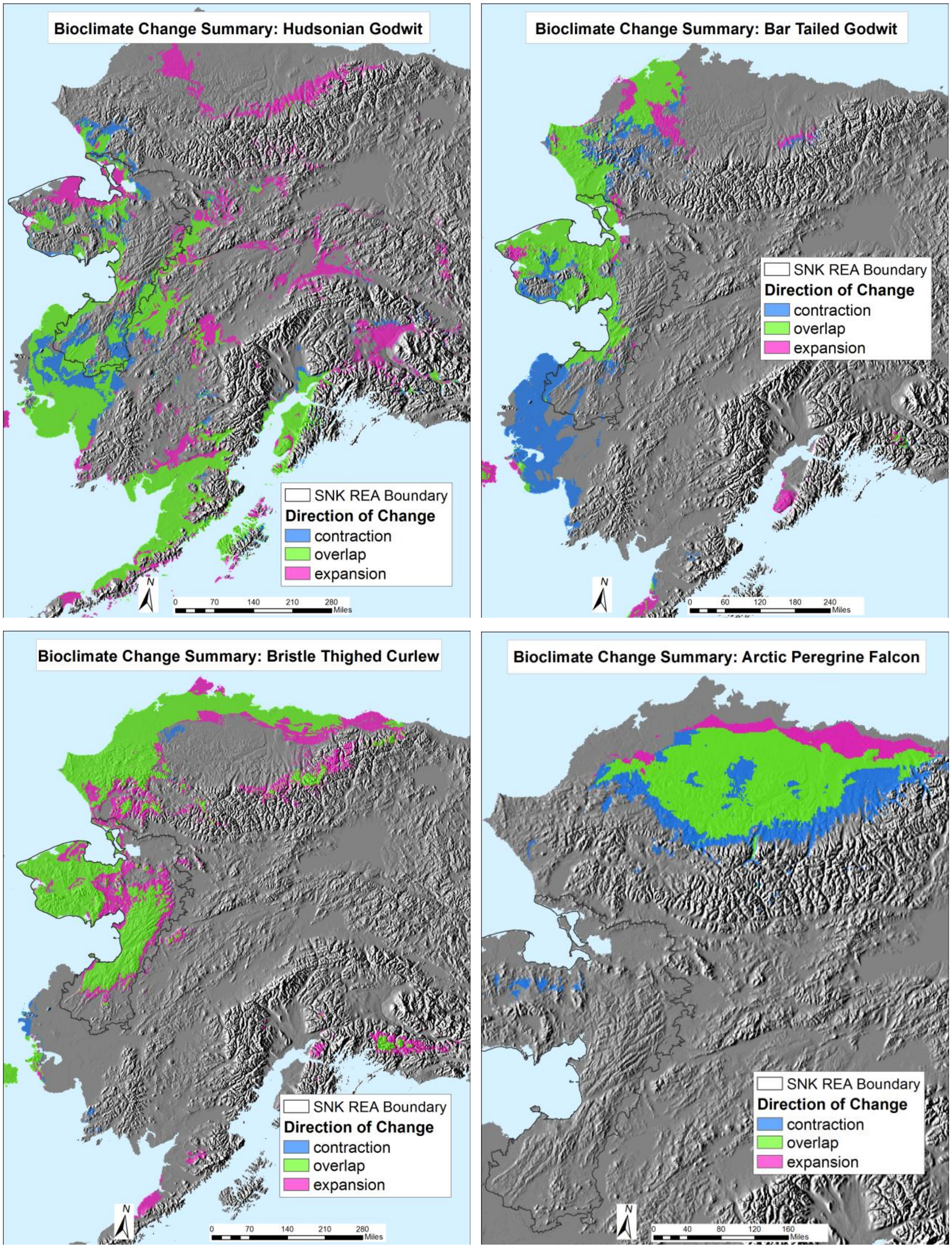
Figure 5-17. Forecasted climate envelope distribution changes for Alaskan hare by 2050s.



5.3.1.3.2 Birds

Breeding birds, with the exception of the Arctic peregrine falcon, show a high percentage of maintained bioclimate within the REA boundary. Hudsonian godwit maintains 55% of its bioclimate within the REA boundary, while bar-tailed godwit and bristle-thighed curlew maintain about 74% of their bioclimate within the REA (Figure 5-18). As shown in Figure 5-18, Arctic peregrine falcon breeding bioclimate shows 100% contraction within the REA, but is maintained in the northern part of its range. The change summary in the northern extent of the breeding range also shows a potential contraction of bioclimate in the foothills and mid-elevations. Based on the relatively limited distribution data available for summer breeding observations, again the interpretation should focus on the areas of overlap between current and future, and the relative loss of suitable bioclimate across these different summer bird residents. Across all four bird species, the largest contractions in suitable bioclimate are at the southern end of the modeled envelope of the bar-tailed godwit. This area may be a good candidate for population monitoring. Large areas of suitable bioclimate are projected to remain in the future in the northern parts of the Seward Peninsula, and if climate change does eliminate southern populations, this potential climate refuge may increase in importance as summer breeding habitat for the bar tailed godwit. The bristle-thighed curlew is projected to experience relatively little loss of bioclimate across its current summer breeding range. Overall, these results suggest that, across all four species, the climatic conditions they currently experience at summer breeding sites will not vanish by midcentury. But these birds face many threats at different life history stages, and continued monitoring is essential to informed management of these conservation elements.

Figure 5-18. Forecasted climate envelope summary for Hudsonian godwit (upper left), bar-tailed godwit (upper right), bristle-thighed curlew (lower left), and Arctic peregrine falcon (lower right) by 2050s.



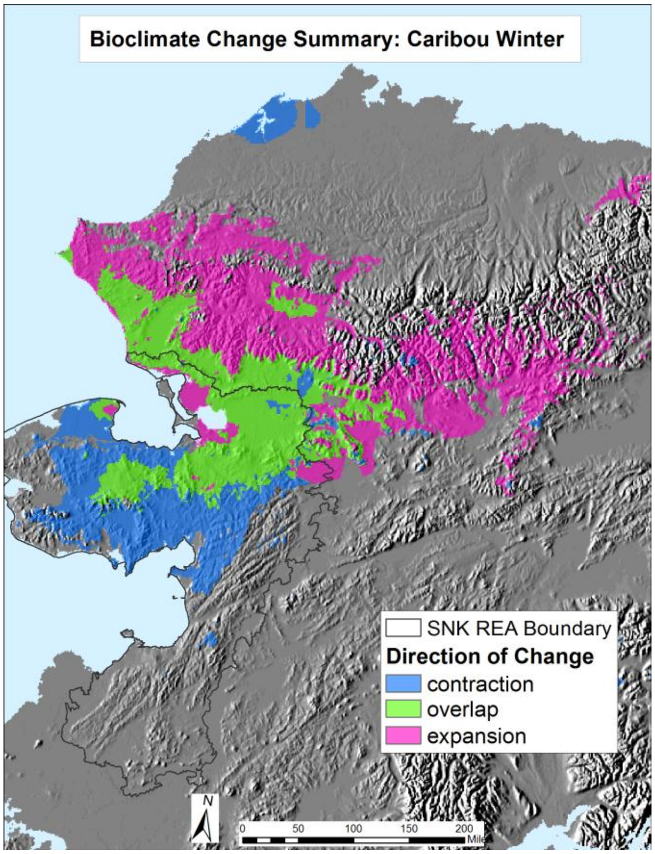
5.3.1.3.3 Subsistence Species

> **103**: Will suitable habitat for caribou be available with climate change? **Is suitable winter habitat for caribou vulnerable to climate change**? or What is the potential impact of climate change on the suitable climatic conditions for the winter range of the Western Arctic caribou herd that frequents the Seward Peninsula?

As noted previously, two habitat components for the Western Arctic Caribou Herd were identified for bioclimate modeling. As shown in Figure 5-19, the change summary for caribou winter bioclimate illustrates a clear shift of suitable conditions to the north, with contraction in the southern part of the range within the SNK REA. There is a portion of the current range, in the northeastern part of the ecoregion, which is projected to retain suitable winter bioclimate for the modeled caribou population. In considering these results, it is essential to keep in mind the management question as it applies to caribou, and the limited winter season distribution dataset that was used in the modeling effort. The question for caribou could be framed as: *What is the potential impact of climate change on the suitable climatic conditions for the winter range of the Western Arctic caribou herd that frequents the Seward Peninsula?* The model results cannot be generalized for Alaska caribou. The most appropriate way to interpret these results is to focus primarily on the regions of overlap, where suitable bioclimate today is projected to be retained into midcentury. The modeled contraction and expansion of habitat are less reliable, because the full range of conditions to which Alaska caribou are adapted are not included in the locality data used as model input.

Globally, caribou are broadly distributed in both tundra and taiga habitats of pan-Arctic boreal ecosystems. They can be relatively nomadic, are flexible in their summer forage habits, and their distributions are not likely to be strongly controlled by a limited set of climate variables. Modeling the current and potential future bioclimate distribution for a single herd, as requested by the AMT for this REA, may produce erroneous conclusions by defining a bioclimatic envelope with values more restricted than those in which the species can actually occur. This may be why models of the future bioclimate distribution of the winter range of the Western Arctic Caribou Herd have low model validation scores (see Appendix B, section B-2.1.3.2).

Figure 5-19. Forecasted climate envelope changes for *winter range* of Western Arctic Caribou Herd by 2050s.



Summary tables are also useful for answering management questions by summarizing all model results and looking at patterns of change in the distribution of suitable bioclimate under future climate scenarios within the SNK boundary. These summaries use the change summary layers, which are rasters of the difference between 2050 and current for each species. From this layer the percent of pixels (area) projected to contract, overlap, or expand from the current bioclimate can be determined for each species. Each species change summary layer was clipped to the SNK boundary, so it is important to note that these tabular results do not represent the entire modeled bioclimate of the species. For example, Arctic peregrine falcon shows 100% contraction in 2050 within the SNK boundary (Table 5-6), but most of their suitable bioclimate is outside the SNK in northern Alaska. Although Arctic peregrine falcon breeding habitat might be vulnerable to changing climate conditions within the SNK, there is maintained suitable bioclimate in northern Alaska (as shown in Figure 5-18).

Table 5-6. Tabular summary of suitable bioclimate change in 2050s within the SNK REA. AUC (Area Under Curve) is listed to show confidence in model results; see Appendix B section 1.2.1.2 for information about AUC and model evaluation.

CE/CA	Species	% Contraction	% Overlap	% Expansion	AUC
Mammal	Alaskan hare	8	82	11	.961
Birds	Arctic Peregrine Falcon	100	0	0	.966
	Bar-Tailed Godwit	20	74	7	.918
	Bristle-Thighed Curlew	0	73	27	.920

CE/CA	Species	% Contraction	% Overlap	% Expansion	AUC
	Hudsonian Godwit	21	55	24	.965
Subsistence	Caribou: Winter Range	55	38	7	.638
Invasive CAs	Orange Hawkweed	0	0	0	.953
	White Sweetclover	0	0	0.4	.972

5.3.1.3.4 Bioclimatic Envelope Modeling Assumptions and Limitations

Results from bioclimatic envelope analyses should be carefully considered in light of the limitations and uncertainties that constrain virtually all scientific efforts to understand the potential impacts of changes in climate. This is particularly true when the analysis objective requires an understanding of current and future climate conditions at fine spatial and temporal scales relevant to plant and animal populations of management concern. Each of the data inputs and modeling tools has associated limitations and uncertainties that contribute to interpretation in modeling results.

Species occurrence data: A rapid ecoregional assessment must utilize already existing datasets, which creates some limitations. Our knowledge of biodiversity distributions is based on observation records, which are often biased. The locality data may not have been intended for this kind of analysis, or are incomplete. For example, some of the breeding bird localities are sparse and may not have represented the full distribution of the species. Also, the invasive species data showed significant sample selection bias in that localities were mainly along roads. This creates issues of accuracy in a model that defines a species climatic niche based on the input data. Thus, input data quality should be considered before interpreting results.

Climate data: Assessing climate change impacts to biodiversity requires gridded spatial climate data for both the current and the future. For the current, interpolated weather station observations establish baseline climate conditions that are used as input into species distributions modeling algorithms, providing baseline modeled distributions from which to measure potential climate-induced changes. Interpolating point observations from weather stations introduces some uncertainty, particularly for precipitation in regions of complex topography.

Understanding the impacts of future climate change on biodiversity requires outputs from global or regional climate models. No single climate model outperforms all others in reproducing patterns of observed climate across the globe, which is the primary way climate model performance is evaluated. The climate modeling community supports the concept that multi-model ensembles generally outperform any single climate model in reproducing observed patterns of global climate (Tebaldi and Knutti 2007). However, for this REA, the models selected for downscaling by SNAP had already been chosen based on an evaluation of model performance across all IPCC 4th Assessment models. Therefore, we have the advantage of examining not a general average of untested models for the region, but the best five models after rigorous screening. Comparing results across this range of models supports an evaluation of model agreement, which is one approach to decreasing uncertainty in future climate impacts assessments (Tebaldi et al. 2011). Also, the coarse spatial resolution of global climate model outputs must be *downscaled* to finer spatial resolution when analyzing climate change impacts to biodiversity. Downscaling assumes that the relationships observed between climate and topography today, such as cold air drainage into valleys, will be maintained into the future.

Bioclimatic envelope modeling: Niche models (such as bioclimate envelope models) make several simplifying assumptions. They do not account for the varying dispersal ability of different taxa; they do not consider genetic or evolutionary adaptive potential across individuals or populations, and they do not account for the influence of biotic interactions. For this REA, we worked with the AMT to narrow the initial list of candidate species for bioclimatic envelope modeling, in order to choose species whose distribution is strongly influenced by climate. However, there remains a recognized element of oversimplification inherent in ecological niche modeling.

Due to these limitation and uncertainties, these REA results are most useful to understand the relative threat of climate change to the modeled current bioclimate envelopes (as shown in the Current Conditions chapter) of the studies species – that is, which species may be more at risk than others? The result of the bioclimatic envelope models can help BLM prioritize which species might warrant further study or monitoring, or at least the need to exercise the precautionary principle in considering the impacts of management decisions. In addition, the climate envelope shift results are better suited to focus on where the current *climate envelope* is projected to remain stable for a given CE, rather than trying to understand where a species might live in the future.

5.3.2 Fire

129: What is the fire history of the region and what is the potential future fire regime? What are the implications for vegetation?

87: How will habitats that support terrestrial species of concern likely change due to fire over the next 15 and 50 years?

Despite difficulties calibrating the ALFRESCO model to deal with the shrubby/deciduous vegetation class prevalent in some areas of the SNK REA, modeling results clearly indicate an increase in fire frequency across the future time period (2025 and 2060). All five GCMs used by SNAP offer similar results (Figure 5-20).

Modeling difficulties related to deciduous/black spruce trajectories, as described under Methods, mean that results should be considered on a location-by-location basis, with greatest credence given to results in locations for which the model is more appropriate. This includes areas of tundra and areas where post-fire forest succession from deciduous vegetation to black spruce or white spruce forest can be expected to occur, based on recent or existing vegetation patterns. It excludes areas of shrubby or riparian deciduous vegetation when such succession does not generally take place.

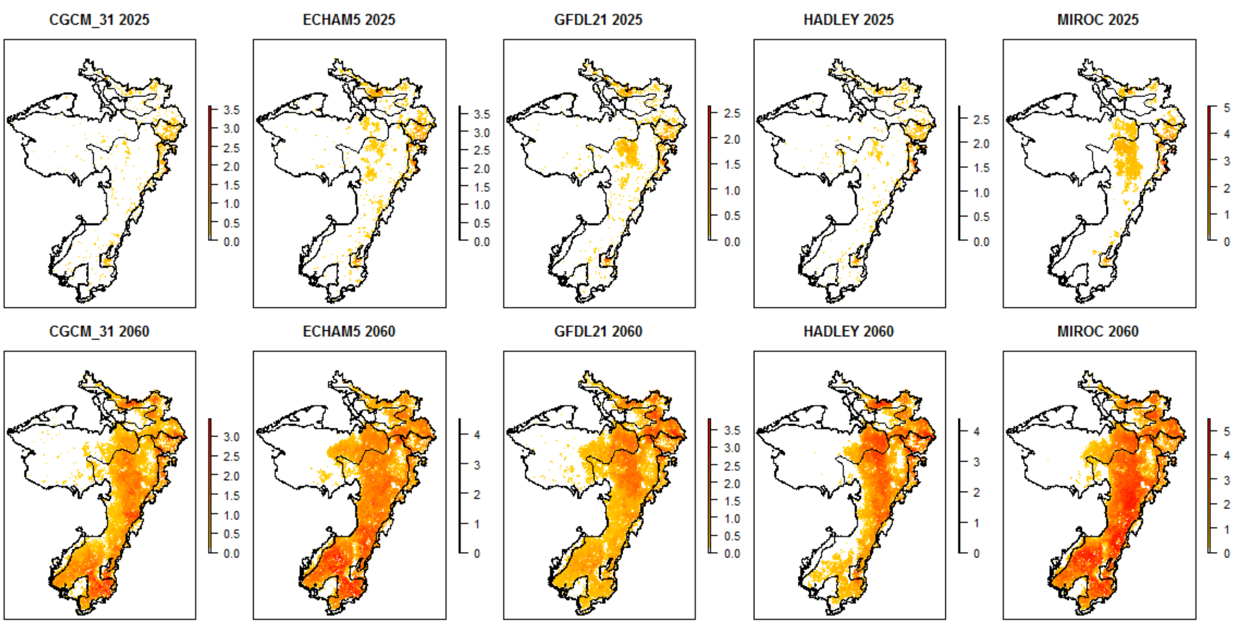
Results indicate that more frequent tundra burning is very likely, and fire cycles in spruce forests will shorten. As described in the Current Conditions chapter, average ecoregional historical fire cycles are estimated to range from approximately 200-350 years in Nulato Hills, Seward Peninsula, Kobuk Ridges and Valleys, Tanana-Kuskokwim Lowlands, and Yukon River Lowlands, although the actual range at is wider at fine spatial resolution, based on local variations in cover type.

Modeled results show (for 2010 to 2025) almost no presence of fire on the landscape for most tundra areas, and fire probabilities of up to about 1-3% annually for areas of black spruce forest. This translates to fire cycles of 33 to 100 years for these most fire-prone sites, and longer fire cycles elsewhere, in the near future. However, model results for the more distant future (2045 to 2060) show a stark contrast, with some forested areas of the Nulato Hills, Seward Peninsula, Kobuk Ridges and Valleys, Tanana-Kuskokwim Lowlands, and Yukon River Lowlands exhibiting annual fire risks of up to 5%. This is equivalent to a fire return interval of only 20 years – too short to allow for the regrowth of late-succession species. In other words, increased fire frequency may result in a marked shift from spruce to early-succession hardwoods in areas that are currently spruce dominated.

The management implications of this potential change are several. More frequent tundra fires throughout the SNK ecoregion, but particularly in the Seward Peninsula ecoregion, are likely to have direct ramifications for caribou and other tundra species, given the slow regrowth rates of lichens post fire measured by Joly et al. (2007), who noted that increased fires in the tundra of western Alaska could decrease the availability and quality of winter habitat available to caribou and reindeer for up to 55 years, potentially resulting in reduced sustainable harvest levels. In forested areas, more frequent fires may reduce caribou wintering habitat and increase browse for moose and other species dependent on early-succession vegetation.

Furthermore, increased fire may have feedbacks to climate-driven vegetative change and to permafrost thaw. In areas where shrubbification is already occurring, fire may allow for more rapid shifts from old vegetation patterns to new ones, spurring the post-fire succession of habitats that better match new climate envelopes. In cases where most of the organic layer burns during an intense fire, subsequent heat transfer to the ground will be increased (Yoshikawa et al. 2002). Given that GIPL models already predict increased permafrost thaw across the region, the coupled effects of fire and permafrost may have profound impacts on the ecosystem.

Figure 5-20. Projections of annual fire risk for two time periods (2025 and 2060) based on five different climate models. Annual fire risk is calculated as the % of times a pixel is projected to burn, averaged across 60 ALFRESCO replicates and over a 15-year time period prior (i.e., 2010 to 2025, and 2045 to 2060). The legend scale to the right of each graphic refers to % annual fire risk.



5.3.3 Development

5.3.3.1 Summary of Future Intensity

Projected development in the SNK ecoregion over the next 15 years is expected to be relatively limited in terms of the size of the area affected. The likely major additions or changes that extend beyond the footprints of current development features are a deep-water port, roads or possibly railroads to support the port and the Ambler mining district (which is located to the north outside the SNK ecoregion), and the relocation of some Native communities.

There is a push at the US national level to build a deep water port in the Arctic to facilitate the development of natural resources in the Arctic. Two locations are under consideration for the port: Cape Darby, located east of Nome in Norton Sound, and Cape Blossom, located south of Kotzebue on the

Kotzebue Peninsula. Cape Blossom would have the shortest road/railroad access to the minerals coming out of Ambler mine (250 miles), compared to Cape Darby (340 miles). But Cape Darby would be a true deep water port, whereas Cape Blossom would need to be dredged. The footprints/development impact of these proposed port sites would be locally substantial but relatively insignificant at the ecoregion scale. Regular dredging of the proposed Cape Blossom port would affect local benthic ecosystems.

The construction and use of a potential road/railroad corridor from either of these ports through the interior of the ecoregion, to bring materials to and from the Ambler mine, might have more significant impact on the landscape. While the Ambler mining district is outside the ecoregion, three of the eight proposed road/railroad corridors scenarios run through the SNK ecoregion. A road/railroad corridor is a potential barrier for migrating ungulates, a pathway for invasive species, and may negatively affect natural hydrologic processes and fish species.

A short road from Kotzebue to Cape Blossom will soon be constructed, but is not expected to have a significant development impact. The proposed road from Nome all the way to Fairbanks via Manley Hot Springs, through the interior would have more impact on the landscape, and is desired by many people in the region, but apparently has little chance in the foreseeable future of being funded by either the state or federal government.

Shorter winters, warmer winter weather and thawing permafrost will impact winter trails/ice roads used to connect small communities.

Human populations are projected to decrease in smaller communities, but increase in medium and larger communities. Kotzebue, Brevig Mission, Selawick, Stebbins and Marshall are projected to have the largest increases in total population, and therefore may experience a concurrent increase in the areal extent and impact of their community footprints.

The coastline on the barrier island community of Shishmaref is rapidly eroding and in the near future the entire community will be relocated to the mainland at Tin Creek. The current community of Shishmaref will become a contaminated site (e.g., abandoned fuel tanks) and potentially impact breeding bird colonies and marine mammals that migrate to the island after it is abandoned. Many other communities located along the coast, such as Shaktoolik and Unalakleet, are also experiencing rapid erosion, and in the future may face the same difficult choice as Shishmaref.

There is currently no additional military development proposed in the ecoregion; however, the further opening up of the Arctic through the construction of a deep-water port and a road/railroad corridor from Ambler mine, would likely lead to increased military presence in the region.

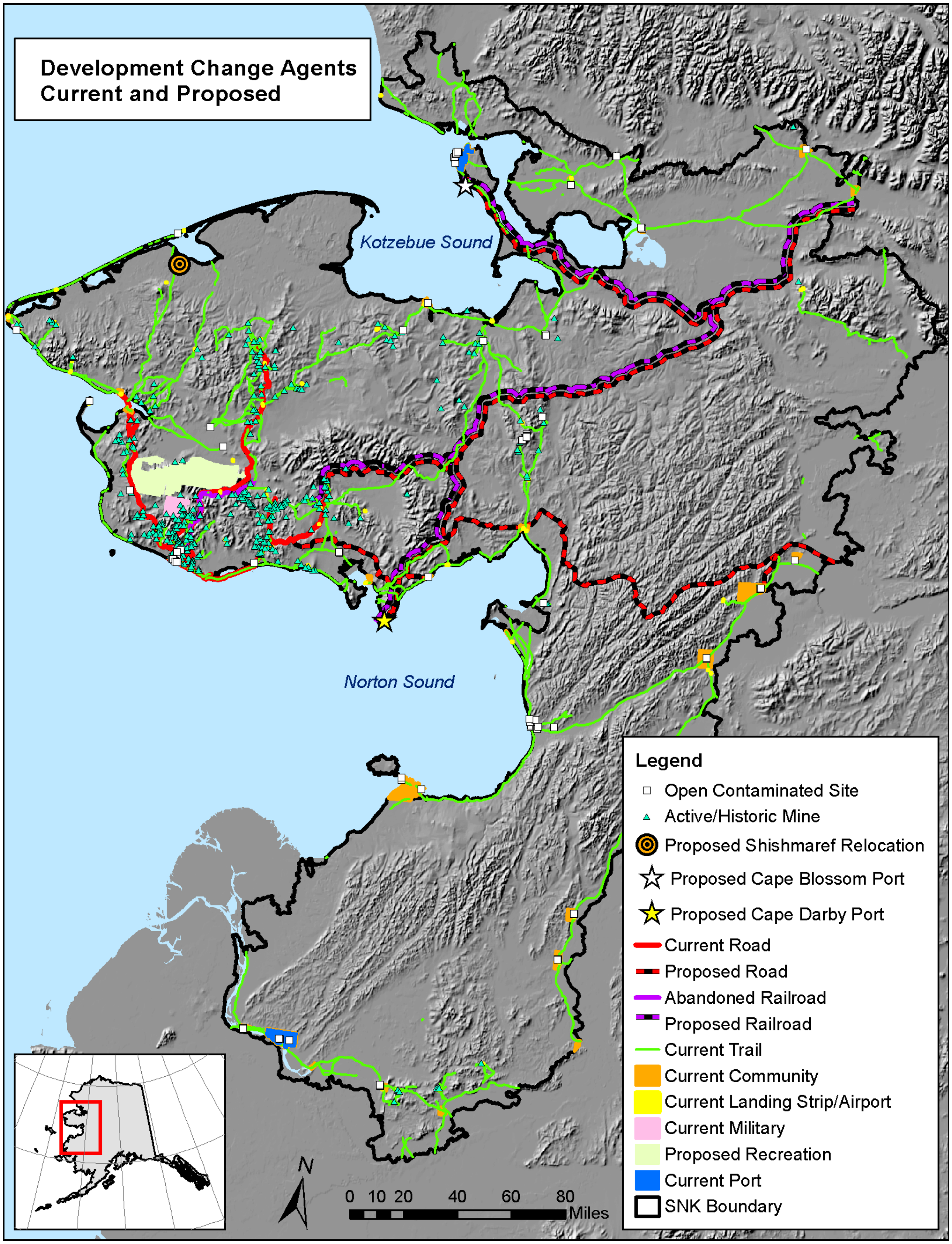
Currently, there is little to no recreation in the SNK ecoregion that is of the scale or impact seen in more densely populated areas of the US. Interior access and ATV use on trails is primarily by subsistence hunters and extremely low use. A proposed Salmon Lake Kigluaik Special Recreation Management Area (SRMA), north of Nome, with potentially higher future recreation use (e.g., camping/fishing) may impact local ecosystems/species. In particular, Arctic char, a fish CE with a small distribution that only occurs within this SRMA, may be impacted.

The two potential mining areas affecting the ecoregion are Big Hurrah (part of Rock Creek mine) in Nome, which is not currently operational but could become active, and mines in the Ambler district (north of the ecoregion), which is still in early exploration stages.

Current and future renewable energy development in this ecoregion is limited to small-scale operations within communities to serve the power needs of local Native communities, with no transmission lines between communities, and little development impact.

Compared to the size of the ecoregion, the footprints of these current and planned development projects are relatively small (Figure 5-21). They will predominately have or will result in habitat loss, fragmentation, and degradation locally. But none of these current or planned development change agents have pervasive impacts throughout the region in the same manner as climate change.

Figure 5-21. Existing development and proposed development features in the SNK ecoregion. Note that not all roads, railroads or ports shown will actually be developed; however, all potential alternatives are displayed.



5.3.4 Invasive Species: Non-Native and Nuisance Native Species

As noted previously, the non-native Norway rat has been documented in Nome. Norway rats are responsible for reductions in biodiversity of insular avifauna, and are exceptional nest predators. Additionally, Norway rats provide supplemental prey to introduced foxes, which also prey on native bird species. AKNHP ranked this species with a very high degree of invasion potential – 91 on a scale of 0 to 100 (Gotthardt and Walton 2011). Once introduced, they readily establish on nearby islands or beaches (MacDonald and Cook 2009). Numerous seabird colonies are located along the Seward Peninsula coast. If rats do spread into these areas, it could be catastrophic to seabird populations, particularly during the nesting season when birds are especially vulnerable. As summarized in AKNHP's species characterization, they readily hitch-hike via airplanes or ships. Expansion from their current location in Nome is likely, and if the SNK ecoregion does become more accessible with new Arctic shipping routes and tourism increases, the potential for new introductions in or near the ecoregion increases. The potential impacts of a rat invasion are far reaching and may also indirectly impact marine intertidal communities by reducing densities of intertidal foraging birds, which in turn may cause intertidal communities to shift from algae to invertebrate-dominated because marine herbivores are released from predation.

The abundance and distribution of non-native plants in Alaska as a whole is changing rapidly (Carlson and Shephard 2007, Conn et al. 2008). Change in the range of any species is a function of spatial alteration of suitable habitat, dispersal potential to those habitats, and adaptation to new habitats. Climate is well accepted to be a major component in determining habitat suitability for invasive plants (see Broennimann et al. 2007) and is likely to interact directly on habitat suitability, for example, by increasing growing degree days or increasing available soil moisture through precipitation. Climate change is also expected to have indirect impacts on habitat suitability of non-native species by two mechanisms: alterations to disturbance regimes and alterations to antagonist and mutualist populations. Increases in fire frequency and extent are likely to elevate susceptibility of Alaskan habitats to non-native plants (Villano and Mulder 2008). Likewise, increases in temperature are likely to increase forest pest populations, such as spruce beetles (see Berg et al. 2006). Loss of dominant overstory vegetation and increased open ground is likely to facilitate non-native population establishment. Lastly, climate change may affect populations of competitors, herbivores, pollinators, etc., which is likely to influence population growth and establishment of non-native plant species. Such indirect effects are likely to be very important; however, they are beyond our predictive capacity.

Five aquatic non-native species have been documented in Alaska outside of the SNK ecoregion:

- *Procambarus clarkia* (Red swamp crayfish; known from the Kenai Peninsula)
- *Pacifastacus leniusculus* (Signal crayfish; known from Kodiak Island)
- *Myxobolus cerebralis* (the whirling disease parasite; documented from the Anchorage Bowl) (McClory and Gotthardt 2008)
- *Gambusia affinis* (western mosquito fish; documented in Alaska, specific location unknown)
- *Elodea canadensis* (pondweed, documented from Fairbanks; Larson et al. 2010)

However, no aquatic non-natives have yet been documented in the SNK, and the potential for spread of these species into the SNK ecoregion is currently unknown. Non-native crayfish may cause significant changes to assemblages of native aquatic species by outcompeting native crayfish or amphibians, reducing amphibian populations through predation, or spreading crayfish fungus plague (*Aphanomyces astaci*) (NBII & ISSG 2011). Red swamp crayfish, documented from the Kenai Peninsula may be introduced as bait, when aquarium pets are released, or when used for culinary purposes (NBII & ISSG

2011). It is unclear how readily this species might spread elsewhere in Alaska, but given its mode of introduction, the risks for SNK may be relatively low. Whirling disease affects salmonids and is having drastic impacts on salmon species in other parts of the U.S.; the parasite causing the disease is virtually indestructible, commonly spread via living infected fish but also readily spread by contaminated fishing equipment, and causes direct mortality to the infected fish (NBII & ISSG 2005). It is currently found in the "Anchorage Bowl." In southeast Alaska, the host worm species for *M.* cerebralis (*T. tubifex*) was not encountered, and suitable habitat for the host may be limited; consequently, it is unlikely that whirling disease would become established in this area (Arsan and Bartholomew 2008). Although *T. tubifex* was abundant at many locations in south central Alaska, the varieties documented are primarily non-susceptible lineages, which may reduce the risk of establishment. Given these factors, the risk of whirling disease spreading into the SNK ecoregion in the near future may be relatively low. *Elodea canadensis* is generally initially introduced from aquaria and spreads as stem fragments floating downstream and between catchments via boating equipment (propellers, trailers, etc.), vehicles, or wildlife (Bowmer et al. 1995). While mosquitofish have a range of negative impacts on native species, they are generally not cold tolerant and may require springs to overwinter in cold regions (e.g., Colorado and Nebraska; Haynes 1983, Woodling 1985); consequently, their spread to other parts of Alaska may be limited. Immediate implications for management within the SNK are general monitoring of these species' documentation in other parts of Alaska, as well as efforts to control their spread.

5.3.4.1 Bioclimate Envelopes: Invasive Plants

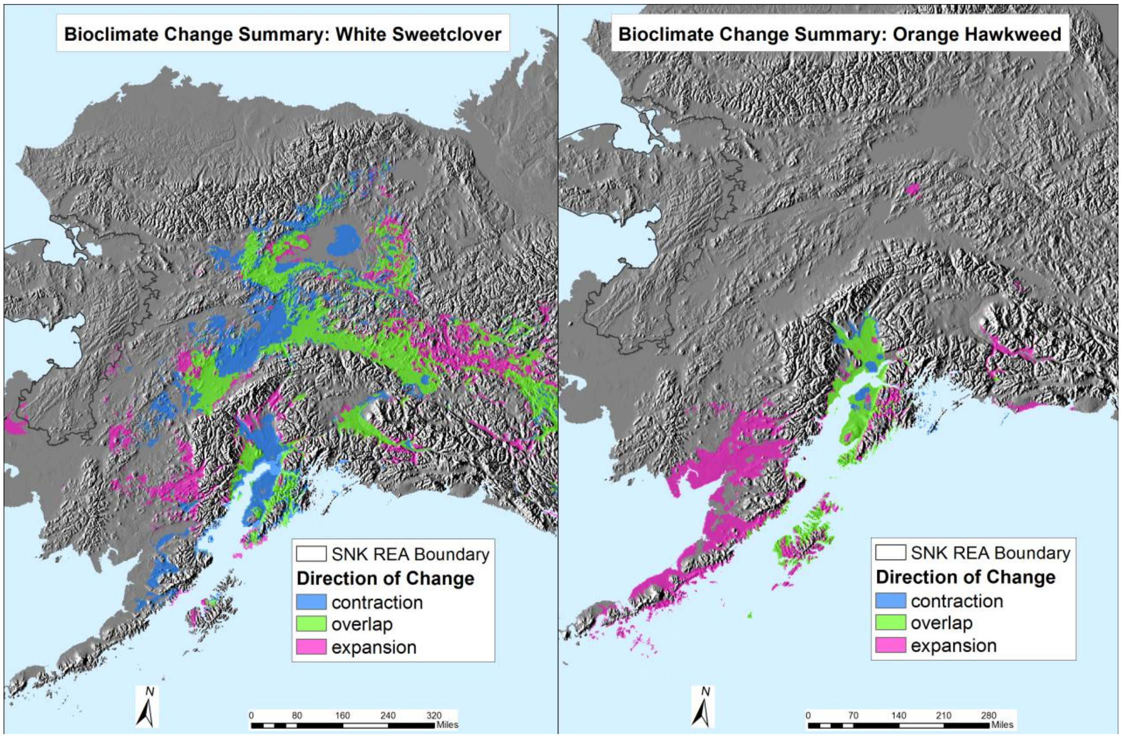
139: Given current patterns of occurrence, what is the potential future distribution of invasive species included as CAs?

Among the four invasive plant species currently documented near the SNK ecoregion and thought to pose a higher risk of invasion into the ecoregion, two were modeled to assess where future climate conditions in the SNK might be within their temperature and precipitation tolerances or envelopes. White sweetclover was run with a spatial extent that included a small portion of Canada because the distribution of the locality data extended into Canada. This was the only species that required climate surfaces to extend into Canada. Results for white sweetclover should be interpreted with caution due to sample selection bias (locality data mainly sampled along roads) potentially influencing model outputs.

As shown in Figure 5-22, temperature and precipitation values that are projected for the SNK into the 2050s are not within the climate tolerances or envelopes modeled for the invasive species white sweetclover (*Melilotus alba*) and orange hawkweed (*Hieracium aurantiacum*); all areas of future suitable climate are outside of the SNK REA area. These results would suggest it is unlikely that these species would invade the SNK REA. However, sweetclover has become widespread throughout North America since it was first introduced. The relatively limited locality data (Alaska and small part of Canada) available for modeling this species for this REA are unlikely to reflect the full range of its climate tolerance as expressed in its current distribution (see Gucker 2009); based on the climate envelope that could be developed, it is unclear how likely it is for sweetclover to invade the SNK ecoregion in the future. Further modeling using a geographically broad selection of locality data and additional environmental variables may provide a clearer indication of risk of invasion of this species. In the absence of additional modeling, its dispersal via waterways suggest monitoring for this species along streams and rivers in the SNK ecoregion that are hydrologically connected to stream systems where it is currently present in other parts of Alaska. In addition, to the extent that roads proposed in this ecoregion are constructed, consideration should be given to construction and revegetation plans, to reduce potential for the introduction of this or other invasive plants.

Although orange hawkweed is relatively widespread in North America, its distribution is patchy. As is the case with *M. alba*, the locality data available to model its bioclimate envelope for this REA were limited (to Alaska-only records), but may be closer to its actual envelope given its more limited distribution. Carlson et al. (2008) note the potential for invasion into ecogeographic regions of which the SNK is a part. As summarized by Carlson et al. (2008), it is readily dispersed by people, animals, and wind, and has been observed in a variety of habitats; in the absence of additional modeling, general monitoring is indicated.

Figure 5-22. Forecasted climate envelope changes for white sweetclover and orange hawkweed by 2050s.



5.4 CA Relationships to CEs

A series of management questions asking about the relationship of CAs with CEs were identified. A brief summary of how these were addressed in relation to 1) climate, 2) fire, and 3) invasives is provided below. Immediately following this summary, the results of the analysis conducted to address these questions in relation to the development change agent are provided.

62: Where do current CE distributions overlap with CAs?

68: What CE populations and movement corridors overlap with CAs?

105: Where will current populations of reindeer experience overlap with Change Agents?

64: Where are CEs whose habitats are **systematically** threatened by CAs (other than climate change)?

As illustrated by the results of the climate trends modeling, climate change is a pervasive threat in this ecoregion; change has already been documented (as shown in 2020s results in the Future Conditions chapter), and continued change is projected. Broad impacts of these changes to date have been documented in this ecoregion (e.g., 10-km treeline shift per Lloyd et al. 2002). Without knowing a CE's range of tolerance for temperature and precipitation (or other climate variables), a simple spatial overlay of current climate variables (e.g., average January precipitation over the last ten years) with *individual* CE distributions – as implied by "Where do CEs overlap with [climate change] CA? – doesn't yield useful information about climate and CEs. To evaluate climate change at the level of individual CEs, the climate envelope models were identified as the approach for addressing that relationship in this REA; these were proposed for a subset of species CEs. They provide a spatially explicit indication of areas where suitable climate is currently available for these species CEs. (In the Future Conditions chapter, they provide an indication of where suitable climate is projected to be in the future for the select species CEs.)

Fire is a natural ecosystem process; however, in conjunction with climate change, alterations from the reference or natural fire regime are similarly expected to cause substantial changes in ecosystems of this ecoregion. Fire regimes are typically characterized as average return intervals for broad vegetation types (e.g., black spruce cover) or for entire ecoregional units (e.g., Nulato Hills). Rather than attempting to identify an appropriate fire layer to conduct a simple spatial overlay with individual CE distributions, the ALFRESCO model, which evaluates vegetation succession dynamics under the interacting influences of climate, fire, and other variables, was selected as the tool for understanding the relationship between fire (and climate) and vegetation in this REA. These results are discussed in the Fire section preceding this section.

Based on the currently available spatial distributions of invasive plant species, it would not appear that any habitats are *systematically* threatened at this time; however, other invasive species management questions elsewhere in the Current and Future Conditions chapters provide a qualitative indication of potential future threat from invasive species within the ecoregion. In addition, bioclimate models were developed for two invasive plant species with potential to invade this ecoregion; those are discussed in the Invasive Species section in the Future Conditions chapter.

5.4.1 Development Change Agents and CE Distributions

This section addresses the following management questions specifically in relation to the development change agent. Development infrastructure and features have discrete, relatively well-known and mapped footprints and are readily overlaid with individual CEs to assess overlap. The spatial extent of "CE populations" was represented by the models of predicted habitat for individual species (developed by AK GAP) that are used throughout this REA. Caribou seasonal range extents represented the relevant data available to address "movement corridors" for CEs. Reindeer grazing allotments represented the available data on the spatial extent of reindeer populations.

62: Where do current CE distributions overlap with CAs?

68: What CE populations and movement corridors overlap with CAs?

105: Where will current populations of reindeer experience overlap with Change Agents?

64: Where are CEs whose habitats are **systematically** threatened by CAs (other than climate change)?

The extent of the future development footprint is little changed from the current development footprint. As was the case under current conditions, there is very little overlap between CEs and the projected future footprints of development change agents in the SNK ecoregion, with most CEs still having 2% or less of their extent overlapping with development. Where there is overlap with future footprints, communities and trails are two of the most significant sources of overlap, as is the case currently. The addition of proposed recreation areas adds another significant source of overlap for a number of CEs. However, the low intensity and diffuse nature of recreation in this ecoregion suggests it may have relatively little impact on most CEs, especially coarse-filter types. Overlap results for future development change agents are summarized in Table 5-7.

Future community footprints overlap with 4% of the total extent of estuaries in the ecoregion, and with 6% of the total Arctic Coastal Brackish and Tidal Marsh extent, due in part to the relocation of the community of Shishmaref to the mainland where these CEs occur.

Eight percent of the total mapped extent of seabird colonies overlaps with the future development footprint, compared to an 8.4% overlap with current development footprints. It is the only CE to show a slight decrease in overlap with the development footprint over time. The future footprint reflects the relocation of Shishmaref from its current location on a barrier island to the mainland; this may remove the overlap with the distribution of seabird colonies, which currently cover the entire island.

Arctic char overlaps 100% with the future development footprint. This is because the future recreation footprint (Salmon Lake Kugliak Mountain Special Recreation Management Area) encompasses the entire Arctic char distribution, which has an extremely small and geographically limited extent. The future recreation footprint also overlaps with 11% of the total extent of Arctic Acidic Sparse Tundra and with 4% of the total predicted habitat of Kittlitz's murrelet.

In general, limitations of these results stem from the accuracy of the mapped development footprints and the accuracy of the mapped CEs. (Discussions of accuracy of mapped CE extents are included with their methods summaries in Appendix B; discussions of mapped accuracy of development change footprints are include with the methods for mapping change agent distributions in Appendix A.) With improved map accuracy of these features, the areas of overlap are generally likely to be even lower.

A particular limitation of the assessment of overlap with *future* development is the inclusion of *multiple* alternatives for proposed roads and other infrastructure. The portions of the three *proposed* road/railroad corridor alternatives that would support the Ambler mine and that would extend through the SNK ecoregion are included in the future development footprint map. Ultimately only one route will be selected; therefore, these footprints are over-represented in the aggregated future development change agent footprint. However, road/railroad corridors were mapped as 60 meter wide features on the landscape; thus, they do not encompass a significant portion of the total area of the ecoregion. Users should note that the percent overlap for CEs with roads and railroads shown in Table 5-7 is somewhat inflated due to the inclusion of all three potential routes. However, at less than 0.2% overlap under both current and projected future conditions for each of the CEs, roads and railroads have among the smallest contribution to CA-CE overlap in the SNK.

Table 5-7. Percent of each CE's extent overlapped by future development CAs. Wherever future development footprints overlapped each other they were categorized and summarized as Multiple Development Change Agents. Percent overlap was derived from an overlay of *raster* CE distribution data by *raster* development change agent footprints; therefore the total extent of CEs (even linear features) is summarized as total area (in acres). For ease of reading, the following formatting has been applied:

- **Where development overlaps more than 2% of a CE's total extent, the total percentage of the CE having overlap with development (Total Development Footprint) and the corresponding percentage having no overlap with development (No Development Change Agent) are bolded.**
- **For each CE, the one to three development types having the greatest percent overlap are bolded.**

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agents	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site	Proposed Recreation
Aquatic Coarse Filter													
Headwater Streams	1,285,504	1.481%	98.519%	0.013%	**0.533%**	**0.141%**	0.066%	0.036%	0.012%	-	0.018%	-	**0.662%**
Low-Gradient Streams	371,778	1.189%	98.811%	0.014%	**0.528%**	**0.290%**	0.046%	0.044%	0.012%	-	0.011%	-	0.243%
River	91,989	1.377%	98.623%	0.011%	**0.407%**	0.220%	0.024%	0.102%	0.040%	-	0.009%	-	**0.565%**
Estuary	16,419	**3.943%**	**96.057%**	0.068%	**2.565%**	**1.258%**	-	0.041%	-	-	0.011%	-	-
Lakes: Large and Connected	614,831	1.207%	98.793%	0.005%	**0.637%**	0.126%	-	0.001%	-	-	-	-	**0.437%**
Lakes: Large and Disconnected	119,200	0.829%	99.171%	0.004%	**0.725%**	0.096%	-	0.003%	-	-	-	-	-
Lakes: Small and Connected	78,124	1.514%	98.486%	0.008%	**0.805%**	0.126%	0.002%	0.017%	-	-	0.016%	-	**0.541%**
Lakes: Small and Disconnected	271,994	1.531%	98.469%	0.013%	**1.271%**	0.142%	0.004%	0.008%	-	-	0.004%	-	0.088%
Hot Springs	2	-	100%	-	-	-	-	-	-	-	-	-	-
Aquatic Fine Filter													
Arctic Char	451	**100%**	**-**	-	-	-	-	-	-	-	-	-	**100%**
Alaska Blackfish	408,411	1.149%	98.851%	0.015%	**0.863%**	0.250%	-	0.011%	0.001%	-	0.006%	-	0.003%
Chinook Salmon	89,413	1.980%	98.020%	0.059%	**1.454%**	**0.417%**	-	0.035%	0.004%	0.001%	0.007%	-	0.004%
Chum Salmon	89,027	**2.307%**	**97.693%**	0.076%	**1.491%**	**0.519%**	0.131%	0.063%	0.011%	-	0.009%	-	0.007%
Coho Salmon	73,684	**2.143%**	**97.857%**	0.007%	**0.728%**	0.199%	0.018%	0.130%	0.020%	-	0.010%	-	**1.031%**
Dolly Varden	612,582	**2.146%**	**97.854%**	0.007%	**0.284%**	0.097%	0.129%	0.043%	0.014%	-	0.010%	-	**1.561%**

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agents	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site	Proposed Recreation
Pink Salmon	58,145	**2.749%**	**97.251%**	0.110%	**1.609%**	**0.721%**	-	0.094%	0.022%	-	0.013%	-	0.180%
Sheefish	26,163	**3.875%**	**96.125%**	0.167%	**2.877%**	**0.829%**	-	0.002%	-	-	0.001%	-	-
Sockeye Salmon	18,693	**4.032%**	**95.968%**	0.236%	**2.533%**	**0.797%**	-	0.075%	0.025%	0.002%	0.019%	-	0.345%
Terrestrial Coarse Filter - Ecological System													
Arctic Active Inland Dunes	4,044	-	100%	-	-	-	-	-	-	-	-	-	-
Boreal Mesic Birch-Aspen Forest	1,145,389	0.837%	99.163%	0.010%	**0.740%**	0.074%	-	0.008%	-	0.002%	0.003%	-	-
Boreal White or Black Spruce - Hardwood Forest	1,148,553	1.607%	98.393%	0.007%	**1.541%**	0.044%	-	0.015%	-	-	-	-	-
Arctic Acidic Sparse Tundra	585,060	**11.522%**	**88.478%**	0.004%	0.151%	0.077%	0.021%	0.001%	0.005%	0.003%	0.001%	-	**11.260%**
Arctic Dwarf Shrubland	1,907,556	**3.067%**	**96.933%**	0.010%	**0.467%**	0.064%	0.474%	0.033%	0.013%	0.001%	0.009%	-	**1.996%**
Arctic Mesic-Wet Willow Shrubland	1,274,263	1.473%	98.527%	0.018%	**0.742%**	**0.275%**	0.083%	0.057%	0.007%	0.004%	0.019%	-	**0.268%**
Arctic Scrub Birch-Ericaceous Shrubland	6,118,469	0.952%	99.048%	0.011%	0.193%	0.163%	0.062%	0.057%	0.013%	0.001%	0.024%	-	**0.427%**
Arctic Mesic Alder	2,464,508	1.325%	98.675%	0.013%	**0.520%**	0.077%	0.011%	0.034%	0.006%	-	0.014%	-	**0.650%**
Arctic Dwarf Shrub-Sphagnum Peatland	1,123,465	1.886%	98.114%	0.015%	**1.752%**	0.087%	-	0.017%	-	-	0.014%	-	-
Arctic Coastal Brackish and Tidal Marsh	217,717	**6.123%**	**93.877%**	0.057%	**5.592%**	**0.441%**	-	0.023%	-	0.006%	0.003%	-	-
Large River Floodplain	307,652	1.124%	98.876%	0.020%	**0.969%**	0.130%	-	0.003%	0.001%	0.001%	0.002%	-	-

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agents	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site	Proposed Recreation
Arctic Acidic Dwarf-Shrub and Birch Lichen Tundra	3,204,509	**3.218%**	**96.782%**	0.003%	0.146%	0.058%	0.148%	0.014%	0.001%	0.001%	0.005%	-	**2.841%**
Arctic Shrub-Tussock Tundra	6,065,470	0.503%	99.497%	0.014%	**0.245%**	0.141%	-	0.052%	0.001%	-	0.039%	-	0.010%
Arctic Wet Sedge Tundra	2,730,696	1.213%	98.787%	0.026%	**0.493%**	0.169%	0.243%	0.060%	0.006%	0.001%	0.023%	-	0.191%
Boreal Black or White Spruce Forest and Woodland	5,481,044	0.681%	99.319%	0.008%	**0.556%**	0.067%	-	0.039%	0.001%	-	0.010%	-	-
Landscape Species													
Alaskan Hare	25,957,200	1.761%	98.239%	0.013%	**0.493%**	0.133%	0.099%	0.041%	0.007%	0.001%	0.014%	-	**0.961%**
Arctic Peregrine Falcon	14,241,626	0.820%	99.180%	0.016%	**0.608%**	0.118%	0.009%	0.042%	0.003%	0.001%	0.021%	-	0.004%
Beaver	34,495,854	1.485%	98.515%	0.013%	**0.480%**	0.126%	0.074%	0.043%	0.005%	0.001%	0.019%	-	**0.724**%
Black Bear	15,650,552	0.799%	99.201%	0.008%	**0.681%**	0.082%	-	0.022%	-	-	0.005%	-	-
Black Scoter	21,405,911	1.248%	98.752%	0.020%	**0.818%**	0.177%	0.041%	0.051%	0.006%	0.001%	0.025%	-	0.108%
Brown Bear	28,383,274	1.439%	98.561%	0.011%	**0.422%**	0.116%	0.059%	0.041%	0.004%	0.001%	0.017%	-	**0.767%**
Bristle-thighed Curlew	15,766,519	**2.041%**	**97.959%**	0.011%	**0.309%**	0.155%	0.150%	0.041%	0.010%	0.001%	0.010%	-	**1.353%**
Bar-tailed Godwit	24,460,717	1.627%	98.373%	0.015%	**0.478%**	0.137%	0.105%	0.046%	0.007%	0.001%	0.019%	-	**0.820%**
Caribou	19,939,573	1.543%	98.457%	0.007%	**0.173%**	0.101%	0.119%	0.033%	0.004%	0.001%	0.017%	-	**1.088%**
Cackling Goose	10,043,923	1.356%	98.644%	0.020%	**1.090%**	0.182%	-	0.042%	0.003%	0.001%	0.019%	-	0.001%
Common Eider	3,681,543	1.335%	98.665%	0.044%	**0.947%**	0.226%	0.002%	0.068%	0.012%	0.002%	0.025%	-	0.009%
King Eider	11,620,081	1.457%	98.543%	0.018%	0.187%	**0.202%**	0.175%	0.075%	0.014%	0.002%	0.024%	-	**0.761%**
Moose	25,704,854	1.436%	98.564%	0.013%	**0.385%**	0.142%	0.098%	0.053%	0.005%	0.001%	0.025%	-	**0.713%**
Muskox	19,655,039	1.739%	98.261%	0.012%	0.109%	**0.123%**	0.131%	0.063%	0.008%	0.001%	0.032%	-	**1.261%**
Yellow-billed Loon	4,675,498	0.928%	99.072%	0.012%	**0.250%**	0.185%	-	0.034%	0.007%	0.002%	0.025%	-	**0.413%**

Element Name	Total Area (Acres)	Total Development Footprint	No Development Change Agents	Multiple Development Change Agents	Community	Trail	Military	Road	Mine	Landing Strip or Airport	Railroad	Contaminated Site	Proposed Recreation
Local Species													
Emperor Goose	1,594,157	1.196%	98.804%	0.061%	**0.626%**	**0.236%**	-	0.155%	0.032%	0.002%	0.030%	-	0.053%
Hudsonian Godwit	25,140,906	0.823%	99.177%	0.012%	**0.658%**	0.099%	-	0.033%	0.001%	-	0.020%	-	-
Kittlitz's Murrelet	6,148,101	**4.964%**	**95.036%**	0.014%	0.132%	**0.234%**	**0.419%**	0.074%	0.022%	0.002%	0.016%	-	**4.051%**
McKay's Bunting	12,224,766	1.677%	98.323%	0.021%	**0.778%**	0.121%	0.161%	0.063%	0.010%	0.001%	0.018%	-	**0.504%**
Red Knot	6,499,273	**2.198%**	**97.802%**	0.028%	**0.261%**	0.211%	0.382%	0.113%	0.021%	0.002%	0.036%	-	**1.144%**
Spectacled Eider	11,684,449	1.359%	98.641%	0.025%	**0.692%**	**0.237%**	0.065%	0.070%	0.011%	0.002%	0.027%	-	0.231%
Species Assemblages													
Marine Mammal Haul-out Sites	40,491	1.193%	98.807%	0.059%	**0.384%**	**0.547%**	-	0.096%	-	0.009%	0.096%	0.001%	-
Seabird Colonies	374,131	**8.010%**	**91.990%**	0.152%	**7.011%**	**0.686%**	0.055%	0.074%	0.013%	0.008%	0.011%	-	-
Waterfowl Concentration Areas	10,411,367	1.570%	98.430%	0.022%	**0.972%**	0.176%	0.014%	0.027%	0.002%	0.001%	0.014%	-	**0.342%**
Reindeer													
Reindeer Grazing Allotments	14,016,390	**2.601%**	**97.399%**	0.020%	**0.295%**	0.201%	0.184%	0.075%	0.012%	0.002%	0.030%	-	**1.782%**
Caribou													
WAH Caribou: Migratory Range	3,085,591	0.865%	99.135%	0.019%	**0.591%**	**0.197%**	-	0.030%	-	-	0.028%	-	-
WAH Caribou: Winter Range	14,201,023	0.268%	99.732%	0.011%	0.077%	**0.093%**	-	0.052%	0.002%	0.001%	0.033%	-	-

5.5 Ecological Integrity: Future

Based on the projected changes in climate, loss of permafrost, and continued alterations to the fire regime as modeled for this REA, continued changes to the ecological integrity of the ecoregion as a whole are expected. Future development that has been proposed in the ecoregion to date is expected to be relatively limited in geographic extent; the most significant development-related consideration for this ecoregion (which was not included as a specific area of assessment for this REA) may be whether the opening of Arctic sea ice results in new ports, trade routes, and related economic development in the region. In both the nearer and longer term, on-going changes in climate, permafrost, and fire regimes are expected to be the main drivers of widespread ecosystem change. As summarized in the Current Conditions chapter, it is likely that continued shifts in the distributions of individual species will, in particular, change the character of the vegetative communities of the ecoregion, and eventually animal species assemblages as well. Changes in permafrost are expected to alter the hydrology of lake and stream ecosystems. The limited results for climate envelope modeling for two invasive species don't provide a clear indication that they will readily invade. Given the species that are currently documented in and around the ecoregion, and their modes of invasion, invasive species may be a relatively lesser driver of ecosystem change in the near future (compared to climate, permafrost, and fire). Without extensive and intensive additional modeling, it is difficult to predict how invasions might increase in the more distant future under a significantly altered climate, significantly altered permafrost cover, and altered fire regime. As noted previously, managing for ecosystem changes caused by alterations in major ecosystem processes such as climate change, loss of permafrost, and altered fire regimes presents substantial challenges. At a minimum, on-going monitoring of changes in species composition and distribution in terrestrial and aquatic systems is warranted, as well as field-based and remotely sensed monitoring of broader changes in terrestrial and aquatic systems as a whole is recommended.

6 Recommendations

6.1 High Priority Data and Knowledge Gaps and Recommendations for Additional Study

As remote sensing, GIS, and most conceptual and spatial modeling capabilities have increased along with computing capacity, scale constraints in regional analyses of natural resources have generally been reduced such that relatively fine-scale mapping and analyses at sub-mile^2/kilometer^2 resolutions are feasible. However, even though the spatial resolution of available climate data, which are a key component of REAs, has been improving rapidly, both their spatial and temporal resolution are still relatively coarse (i.e., monthly mean values averaged across decadal time period and 4 km^2 pixels). Some products, such as the results of the permafrost modeling and the ALFRESCO model, contain spatially explicit projections of soil or vegetation changes, but the level of uncertainty of model predictions *at the scale of individual pixels* is such that these results must be viewed in terms of their broader trends within the ecoregion (or within reporting units such as 5th-level HUCs). The variety of scales and resolutions reflected in REA products are dependent on the source data and modeling methods and represent the finest practical scale of analysis and presentation.

The fact that an REA is, by definition, a rapid and regional assessment that utilizes existing data creates some important limitations:

- REA results are intended to inform landscape-scale direction rather than site-level decision making.

- A substantial number of analyses conducted over a short timeframe were required for this REA, and therefore modest resources were available for each individual analysis. The REA products are useful for the intended purposes, but by design, they are not comparable to the results of intensive, focused, multi-year studies on particular management questions.
- Only data considered relatively complete for the ecoregion could be used; therefore, although certain areas of the REA may have had more recent or higher resolution data, it was not used because it was not available REA-wide.
- Very few source data sets have had rigorous, quantitative accuracy assessments conducted on them; therefore it is infeasible to provide such information for REA results. Instead, qualitative discussions of confidence and limitations were included with the assessment results to provide information on uncertainty to users, but further consideration of source data quality used in each analysis is encouraged.
- As noted elsewhere, limitations in available data were treated throughout the REA process in part by emphasizing transparency, repeatability, and the use of expert judgment. To provide transparency and permit repeatability, both input data and modeling processes were carefully documented in metadata, the appendices to this report, in ArcGIS toolboxes where appropriate, and through other supporting documentation. Expert judgment was used for various decision points in various modeling processes (e.g., developing a manual "spin-up" input for the ALFRESCO modeling); again, these judgments are documented in the appendices to this report, metadata records, and other supporting documentation as appropriate, as well as in appropriate sections of the main report. Limitations are discussed in conjunction with the interpretation of analysis results throughout the report in order to avoid mischaracterization of the results.

Based upon this rapid assessment, numerous gaps in current knowledge and data were identified. Below are high-priority gaps where future investments would be productively focused.

Conservation Element Distributions

The terrestrial coarse-filter CEs were mapped for this assessment by building upon a series of four separate regional vegetation mapping efforts that used different source data (satellite imagery, aerial photos) over different time periods (1978-2011) using varying methods (manual delineation of vegetation types vs. the use of computer-based classification techniques) with varying map resolution (30 meter pixels vs. 1:250,000 vector polygons) and varying resolution of vegetation classifications (ranging from 40 to 79 classes). Ancillary data sets (National Hydrography Dataset, LANDFIRE Existing Vegetation Type data, and 60 meter DEM) were used in combination to distinguish certain types that were not readily identified from the four primary vegetation data sets. Although the variability of the four primary vegetation data sets poses concerns about accuracy, the available standardized vegetation data set (LANDFIRE Existing Vegetation Types) covering this area has an overall accuracy of less than 25% in its current form. The development of a standardized, high-resolution (in terms of both spatial units and vegetation classification) vegetation layer for Alaska should be a high priority. Having a high quality and standardized vegetation layer will benefit any future revisions to the SNK REA as well as any other REAs or other regional or state-wide assessments of vegetation resources.

The quality of mapped vegetation data cannot be adequately evaluated without a robust data set of field samples. The on-going gathering and maintenance of georeferenced samples for all major vegetation types, vegetation structure, and successional status, continues to be of highest priority. Such data are also necessary for other types of modeling, such as bioclimate envelope modeling.

As noted in memo 3, eight fine-filter aquatic CEs listed below lack data with which to map their distributions in the SNK ecoregion. If and when observation data become available to model their distribution, this data gap should be filled.

1. **Arctic lamprey** (*Lampetra japponica*)
2. **Bering cisco** (*Coregonus laurettae*)
3. **Broad whitefish** (*Coregonus nasus*)
4. **Humpback whitefish** (*Coregonus pidschian*)
5. **Pacific lamprey** (*Lampetra tridentata*)
6. **Pike** (*Esox lucius*)
7. **Rainbow smelt** (*Osmerus mordax*)
8. **Round whitefish** (*Prosopium cylindraceum*)

Two species assemblages had been identified for which adequate data were also lacking: sea ice assemblages, and raptor concentrations. If adequate data become available to evaluate these groupings, they should be added to the assessment. It may be worth considering whether sea ice assemblages represent species that are a management priority for BLM.

Landscape species distributions used in this REA are first drafts of models of predicted habitat for these species, developed by the Alaska GAP program. As is discussed in detail in the landscape species modeling section in Appendix B, only models with an area under curve (AUC) of 0.75 or better were considered acceptable and used for this REA. Although the planned refinements of these predictive models are the immediate next step for improving the characterization of landscape species distributions, most landscape species worthy of REA attention ultimately require more specific characterization, mapping, and evaluation of habitat usage and quality, seasonal range, and/or populations. With more accurate distribution information available, the accuracy and reliability of existing SNK assessments (e.g., how do CEs overlap with development change agents or managed areas) can be improved, and other assessments using these data as a foundation could be conducted and yield results with a higher degree of confidence. In particular, when coupling species ranges with climate data, it is important to have good data on species absence as well as presence, so that it is clear what environments cannot support a particular CE.

Because of the importance of caribou in this region, the identification of vegetation types that are highly correlated with caribou usage and located within the updated winter range extent (as shown in Joly et al. 2007, Figure 2, 95% kernel) would be useful. Rather than modeling a bioclimate envelope for caribou, a bioclimate envelope for major forage lichen species found in this ecoregion may be useful. This would require the identification and detailed mapping of vegetation types containing lichen forage or plot data that comprehensively represent the range of lichen habitats. Another possibility is using Maxent to develop a complete model of current predicted habitat for lichens, and using those model results in conjunction with projected future temperature and precipitation to map *future* predicted habitat for lichens. This information and modeling could further inform the question of whether suitable habitat will be available for caribou in a changing climate.

Development Change Agent Distribution

Development patterns across the ecoregion appear to be relatively well described with existing data sets. In addition, development in this ecoregion is not a major driver of change, compared to climate change and its interactions with change in permafrost and fire regimes. A few weaknesses or data gaps are noted, but addressing these should generally be a lower priority in comparison to filling gaps or revising models relating to climate, fire, and permafrost. The contaminated sites data lack standardized information on the areal extent, type, and severity of contamination. Polygons showing community footprints are larger than their actual extent. Attribution of roads and trails data should be improved; the type of road or trail is not consistently specified. Once the final alternatives have been selected for the road and railroad to support the Ambler mine and the deep water port (as well as the port location itself), the future footprints data should be updated to reflect these decisions. While a lower priority relative to climate, fire, and permafrost, additional investments in these particular areas should yield useful outcomes for subsequent assessment and planning.

Aside from considering development change agents independently, linkages between development and climate change should be examined more thoroughly, particularly with regard to the development of new trade routes and trade hubs as Arctic sea ice opens. Increased access in or near this ecoregion could potentially spur radical growth, with substantial impacts on extractive industries, employment, population, uses of public lands, and many other components. While it may require more resources than a “typical” MQ in order to provide useful information around these issues, the potential impacts that could result from increased access to or “use” of this ecoregion are worth investigating.

Socioeconomic and Subsistence Conditions

Change in the ecoregion is occurring at different temporal and spatial scales. Projections of changes in socioeconomic conditions are more accurate over a relatively short time horizon – one to five years – in part because such changes can take place within a short time frame. Socioeconomic predictions for longer time frames have lower accuracy. In comparison, climate change projections are readily modeled for more distant time periods. While the Army Corps’ risk assessment provides useful information on the risk of potential direct impacts on communities, additional research into trends in subsistence harvest levels, subsistence species populations, and potential impacts of changing climate on population trends would be useful.

Socioeconomic conditions in this ecoregion are greatly influenced by political concerns, as well as economic and environmental conditions. As noted above, national decisions about a deep water port or military capability in the Arctic could have significant impacts on the ecoregion, particularly on socioeconomic conditions. Depending on the likelihood of these developments, their potential impact on the ecoregion’s socioeconomic conditions should be investigated.

Boundaries of the ecoregion do not match political or cultural boundaries. Communities are connected by their language group and political boundary. The boundaries of the ecoregion include parts of several boroughs/census areas and native corporation boundaries. Considering cultural “boundaries” may be useful in future assessments of socioeconomic and subsistence conditions.

More information is needed regarding the cost, timeline, and employment associated with community relocations and erosion mitigation measures. Employment estimates were not available at the time of this study but will be useful in future REAs.

Additional information on the impacts of subsistence and commercial fishing on salmon populations would be helpful, in conjunction with an investigation into how climate might impact stream temperatures and salmon populations to understand the potential for change in subsistence salmon harvest.

Ecological Status Assessments

Available data and current modeling tools have constrained the assessment of ecological status of CEs to a relatively limited set of indicators based on anthropogenic infrastructure or footprints (e.g., culverts, placer mine ditches, roads, etc.). Climate, fire, and permafrost modeling approaches and tools can predict broader trends in those change agents, and bioclimate envelope modeling was used to identify areas where species' climate envelopes are likely to shift. The modeling approaches that were finalized in the REA memos and work plan have little or no ability to provide scientifically rigorous indications of ecological status at the resolution of *individual* CEs. Recommendations provided below under "*Fire regime models*" and under "Climate-Related Analyses/*Climate and CEs*" offer suggestions for addressing this.

Landscape condition modeling: Given that the intensity and distance decay settings for landscape condition modeling are expert judgment, considerable potential remains to test, calibrate, and customize the model used in this REA. It may also be useful to review species CEs and determine whether a) custom condition models are useful for a subset of key species, and b) whether meaningful adjustments to intensity and decay scores can be identified.

Fire regime models: If a standardized set of terrestrial coarse-filter CEs can be identified, mapped, and linked with LANDFIRE ecological system types, existing models of fire regimes for these individual ecological systems can be refined as appropriate and then used to develop CE-specific estimates of integrity in relation to fire regimes. This is *not* a recommendation to use the existing LANDFIRE vegetation map data for Alaska, but rather to develop a comprehensive and standardized vegetation layer that can be readily linked to the vegetation types used in LANDFIRE. Having the linkage between a standard set of Alaska vegetation types/ecological systems with the LANDFIRE system would permit the use of existing models of successional dynamics developed for those LANDFIRE types; those existing models could be used and refined as needed to model potential changes in vegetation resulting from projected alterations in fire regimes. While it would be possible to do this within the context of a "typical" REA, it should be noted that investing in this level of modeling would necessarily limit the depth and breadth of modeling that can be done to complete other components of an REA.

Aquatic indicators: As noted in memo 3, aquatic resources in the SNK ecoregion are lacking long-term hydrological, chemical, and biological datasets (e.g., seasonal stream discharge, timing of flow maxima and minima, timing of snowmelt, groundwater recharge, biotic composition, sediment loads, water chemistry data, water temperature, etc.) with which to characterize baseline conditions or infer deviations from reference conditions. There are no known occurrences of aquatic invasive species in the study area and there is also limited information describing vectors for their transmission, potential effects on native aquatic resources, and predictions of future distributions. These are significant data gaps, and it is unclear what data may become available to better evaluate aquatic ecological status. However, as additional data and research findings become available, this is an important area to revisit.

Climate-Related Analyses

Once the climate trends results were completed for this REA, the significance of the climate change that has taken place since 1980 became clearer. In the REA analysis, the period from 1901 to 1981 was used to calculate a 20th century "baseline" climate. Because substantial change has already taken place between 1981 and the present (2010), the model results for the 2025 period were more difficult to interpret, because change that has already occurred could not be distinguished from change that is expected to occur. It might have been helpful to break down this time period into two parts: 1980 to the present, and the present to 2025. In addition, given the earlier signal of significant climate change in the Arctic, it may be more informative to use 1901-1970 as the time period defining "baseline" climate, and the period of 1970 to the present as a period of recent change. A single future time period (2050s or 2060s) could be compared to both baseline and recent climate to determine the degree of projected change. (1970 may not be the precise cut-off year needed; a review of climate data for the Arctic should inform the determination of an appropriate cut-off year.)

Climate and CEs

The current assessment of climate trends focused on two variables – average monthly temperature, and average monthly precipitation. To further investigate effects on CEs, variables such as season length, growing degree days, evapotranspiration or soil moisture would ideally be modeled. Such assessments would provide information on trends in these variables, which can be paired with literature reviews to qualitatively assess impacts on CEs.

Enhancements or expansion of the boreal ALFRESCO model would permit improved projections of successional changes in shrubland and tundra habitats resulting from altered climate and fire regimes in the SNK ecoregion. The work to enhance the model would not be insignificant, but it would benefit not only updates to the SNK REA or subsequent assessments, but similar natural resource assessments throughout Alaska and beyond. Work is current underway to improve ALFRESCO parameters for tundra ecosystems and transitional shrub ecosystems, as well as to allow for vegetative succession among multiple tundra types within the stochastic framework of the model. This would not only reduce error and uncertainty in northern and coastal regions of Alaska, but allow ALFRESCO to be more closely coupled with predictive models of vegetation and ecosystem shift. SNAP has also developed new biome-shift models, and is working on an Integrated Ecosystem Modeling project to link these efforts.

Once a standard set of terrestrial coarse-filter CEs have been mapped with a reasonable level of confidence and consistency, and assuming plot data are available for the CE types across their range, climate envelopes might be modeled for terrestrial coarse-filter CEs as well. The challenge will be the circumpolar or circumboreal distribution of some of the types. Observation data for the full distribution of the type are necessary to build a representative current climate envelope, and the work needed to obtain and classify (into CE types) such range-wide plot data for ten to thirty coarse-filter CEs as a starting point for such modeling would be beyond the scope of an extensive and rapid assessment (or would place limits on the depth of other REA assessment components). The coarse-filter CEs should be reviewed to identify a subset that could reasonably modeled and could provide useful information.

Another consideration with modeling vegetation groupings is the fact that they don't shift as groups in response to changing climate. Individual species shift in individual patterns or trajectories and may eventually form new vegetation assemblages. Therefore, it might be useful to model climate envelopes for a number of the dominant or defining species within the major vegetation categories used in ALFRESCO, such as white or black spruce.

The Alaska GAP program used Maxent to model predicted habitat for most of the terrestrial and many of the aquatic species CEs; these models used a wide range of environmental variables. Maxent was also used to develop the bioclimate envelope models; these models simply defined the upper and lower temperature and precipitation thresholds for species CEs and identified the locations that are projected to be within these upper and lower bounds for a given species in the future. The interpretation of the climate envelope models is challenging without having other habitat-defining variables for reference. Two follow-ups are proposed:

- As the Alaska GAP program refines the species habitat models, the models can be reviewed to identify the subset of species for which climate variables are strong predictors of distribution.
- Then, the GAP models can be built on in the following way for that subset of species, to develop models of their projected *habitat* under an altered climate: the range of values for each of the *non-climate* predictor variables could be combined with the *projected values* for the climate variables (subset to their upper and lower bounds for the species in question) to map areas that would potentially provide adequate habitat for the species under a changed climate. This mapping would be a GIS exercise outside of Maxent, but using Maxent model results.

A technical consideration is whether there is an appropriate approach for dealing with the varying resolutions of climate data (2 x 2 km) vs. the other environmental variables, which would be somewhere between 30 and 90 meters. New SNAP climate data, which became available during this REA, allow for 800 meter resolution. However, climate data at a scale finer than 800 meters may not be meaningful from a modeling perspective, due to high levels of uncertainty. Instead, averaging or smoothing other variables to coarser resolution may provide a more realistic output that does not over-represent the precision of our knowledge of the landscape.

Additional literature review or modeling may shed light on the impacts of increased stream temperature, increased ocean temperature, and ocean acidification on salmon and other aquatic CEs. However, at this point in time adequate research has not been done to determine whether a tipping point is being approached. What can be modeled or assessed with regard to climate change, increased stream temperatures, and impacts on salmon? (Are projected changes in air temperature such that stream temperatures are unlikely to increase to the point where they will affect fish CEs?)

No direct data were available on climate change impacts to aquatic systems, although such changes were extrapolated from SNAP models of air temperature, precipitation, and soil thermal dynamics and qualitatively described. This added an additional level of uncertainty to predictions relating to rivers, lakes, and marine ecosystems – all of which are important to the region. When possible, data gaps were filled by referencing published literature, but better climate-linked aquatic models would benefit future efforts. A particular area of investigation may be better understanding the likely impacts of permafrost thaw on stream and lake hydrology (in permafrost regions throughout Alaska), and how those hydrologic changes are likely to impact salmon and other species, both subsistence and non-subsistence, in the SNK ecoregion.

Invasive Species

Available data on terrestrial and aquatic invasive species locations in the SNK ecoregion are extremely limited or non-existent. No aquatic invasive surveys have been completed, and six relatively limited terrestrial plant surveys have been conducted in the ecoregion. The assessment team had eventually determined that available data and resources permitted the development of bioclimate models for two key invasive plant species currently found near the SNK ecoregion. However, there is a need to better understand the potential for invasions in the SNK ecoregion. A more in-depth review of species that are likely to invade may be useful, coupled with risk assessments or other modeling efforts to identify potential risk in a spatially explicit manner. Models of projected habitat, based on projections of climate envelopes in conjunction with other environmental determinants, and using locality data for the species' entire geographic range, may inform estimations of invasion risk with a higher degree of certainty.

6.2 General Recommendations

Given the above summary of key data/knowledge gaps, the following general recommendations are provided for further study. As noted in the introduction, an almost infinite number of analyses and products are possible with the information developed in this REA.

Among the most important areas of further study will be the use of REA findings to inform ecoregional direction under BLM's Landscape Approach. This new approach implements an adaptive framework aimed at providing a clear focus for investments and clear lines for feedback and continual improvement. REA analyses are intended to provide a useful regional perspective as partners engage together to set priorities for management actions that will be documented in updated resource management plans. BLM is encouraged to consider creating a distinct information feedback from subsequent planning phases to ensure that future ecoregional assessments:

- Engage all appropriate partners in the oversight and guidance given to each REA; clarifying needs for the full array of social, economic, and ecological issues to be addressed.
- Answer the critical management questions in ways that will provide true insight for planning decisions that will be made over the coming decades.
- Organize data in ways that maximize efficiency in data collection, management, model building, and product distribution.

Given the challenges posed by changing climate, fire regimes, and permafrost in this ecoregion, a clear organization-level vision that will direct and inform practical responses and pro-active management strategies for these CAs should be identified or refined. In addition to refining or improving available information on CE distributions, pursuing more in-depth or extensive investigations into climate, fire, and permafrost impacts, as recommended above, are among the top priorities for further study.

Through subsequent planning and management implementation, a series of more specific questions will need to be identified and address to provide important insight for evaluating products of the REA. For example, field implementation and monitoring can present opportunities to:

- Update data on the probable location of conservation elements, their apparent ecological status, and relative responses to various change agents, particularly climate change and fire. These data will support updating CE distribution maps, as well as conceptual and spatial models related to their ecological status.
- Update data on the location, rate, and effects of CA change, particularly climate and fire, to allow rapid re-evaluation of actual and potential effects on CEs and other CAs.
- Validating all model assumptions.

7 References

Ahmasuk, A., and E. Trigg. 2008. Bering Strait region local and traditional knowledge pilot project: A comprehensive subsistence use study of the Bering Strait region. North Pacific Research Board Project Final Report Project #643.

Ainsworth, C. H., J. F. Samhouri, D. S. Busch, W. L. Cheung, J. P. Dunne, and T. A. Okey. 2011. Potential impacts of climate change on Northeast Pacific marine food webs and fisheries. ICES Journal of Marine Science 68(6):1217-1229.

ADFG [Alaska Department of Fish and Game]. 2012. Species profile: Moose. Alaska Department of Fish and Game, Juneau, Alaska. Available on-line: http://www.adfg.alaska.gov/index.cfm?adfg=moose.main (Accessed 20 July 2012).

AKDEP [Alaska Department of Environmental Protection]. 2006. Red Dog Mine Use Attainability Analysis. Alaska Department of Environmental Protection, Juneau, AK.

AKDEP [Alaska Department of Environmental Conservation]. 2010. Alaska's Final 2010 Integrated Water Quality Monitoring and Assessment Report. Alaska Department of Environmental Conservation, Juneau, AK.

AKDoLWD [Alaska Department of Labor and Workforce Development]. 2012. Alaska local and regional information. Alaska Department of Labor and Workforce Development, Research & Analysis Section, Juneau, AK. http://live.laborstats.alaska.gov/alari/

AKEPIC [Alaska Exotic Plant Information Center]. 2010. Alaska Exotic Plant Information Center Database. Alaska Natural Heritage Program, UAA. http://akweeds.uaa.alaska.edu/ (Accessed 15 May 2010).

Alaska Department of Transportation. 2004. Northwest Alaska transportation plan. Alaska Department of Transportation, Juneau, AK. February.

Alaska Natives Commission. 1994. Alaska Native Commission Final Report Volume I. Alaska Federation of Natives, Anchorage.

Alessa, L., A. Kliskey, P. Williams, and M. Barton. 2008. Perception of change in freshwater in remote resource-dependent Arctic communities. Global Environmental Change-Human and Policy Dimensions 18(1): 153-164.

Alonso, W., and E. Rust. 1976. The evolving pattern of village Alaska. Anchorage: Federal-State Land Use Planning Commission for Alaska.

AOU [American Ornithologists' Union]. 1983. Check-list of North American birds. Sixth edition. American Ornithologists' Union, Washington, DC.

Anderson, K., and A. Bows. 2008. Reframing the climate change challenge in light of post-2000 emission trends. Philosophical Transactions of the Royal Society A: Mathematical Physical and Engineering Sciences 366(1882):3863-3882.

Anderson, K., and A. Bows. 2011. Beyond 'dangerous' climate change: Emission scenarios for a new world. Philosophical Transactions of the Royal Society A: Mathematical Physical and Engineering Sciences 369(1934):20-44.

Armstrong, R. H. 1995. Guide to the birds of Alaska. Fourth edition. Alaska Northwest Books, Anchorage, AK. 322 pp.

Arp, C. D., and B. M. Jones. 2008. Geography of Alaska lake districts: Identification, description, and analysis of lake-rich regions of a diverse and dynamic state. U.S. Geological Survey Scientific Investigations Report 2008-521. 40 pp.

Arsan, E. L. 2006. Potential for dispersal of the non-native parasite *Myxobolus cerebralis*: Qualitative risk assessments for the state of Alaska and the Willamette River Basin, Oregon. Masters thesis, Oregon State University, Corvallis. http://ir.library.oregonstate.edu/ jspui/handle/1957/3843.

Bailey, R. G. 2008. Ecoregions Map of North America. USDA Forest Service Misc. Publication No. 1548. 10 pp. + map scale 1:15,000,000.

BEA [Bureau of Economic Analysis]. 2012. Regional Data. U.S. Department of Commerce, Bureau of Economic Analysis, Regional Income Division. http://www.bea.gov/iTable/index_regional.cfm

Begét, J. E., D. M. Hopkins, and S. D. Charron. 1996. The largest known maars on Earth, Seward Peninsula, Northwest Alaska. Arctic 49:62-69.

Berg, E. E., J. D. Henry, C. L. Fastie, A. D. De Volder, and S. M. Matsuoka. 2006. Spruce beetle outbreaks on the Kenai Peninsula, Alaska, and Kluane National Park and Reserve, Yukon Territory: Relationship to summer temperatures and regional differences in disturbance regimes. Forest Ecology and Management 227:219-232.

Berman, M., and G. Kofinas. 2010. Hunting for models: Rational choice and grounded approaches to analyzing climate effects on subsistence hunting in an Arctic community. Ecological Economics 49:31-46.

Berman, M., C. Nicolson, G. Kofinas, J. Tetlichi, and S. Martin. 2004. Adaptation and sustainability in a small Arctic community: Results of an agent based simulation model. Arctic 57 (4):401-414.

Bierwagen, B., D. M. Theobald, C. R. Pyke, A. Choate, P. Groth, J. V. Thomas, and P. Morefield. 2009. Land-use scenarios: National-scale housing-density scenarios consistent with climate change storylines. EPA/600/R-08/076F. U.S. Environmental Protection Agency, Global Change Research Program, National Center for Environmental Assessment, Washington, DC.

Bjerklie, D. M., and J. D. LaPerriere. 1985. Gold-mining effects on stream hydrology and water quality, Circle Quadrangle, Alaska. Journal of the American Water Resources Association 21:235-242. (doi: 10.1111/j.1752-1688.1985.tb00133.x)

BLM [Bureau of Land Management]. 2006. Kobuk-Seward Peninsula Resource Management Plan and Environmental Impact Statement, Chapter III: Affected Environment. U.S. Department of the Interior, Bureau of Land Management. April.

Boggs, K., and M. Sturdy. 2005. Plant associations and post-fire vegetation succession in Yukon-Charley Rivers National Preserve. Prepared for National Park Service, Landcover Mapping Program, National Park Service-Alaska Support Office, Anchorage. Alaska Natural Heritage Program, Environment and Natural Resources Institute, University of Alaska, Anchorage.

Boggs, K. W., M. Sturdy, D. J. Rinella, and M. J. Rinella. 2008. White spruce regeneration following a major spruce beetle outbreak in forests on the Kenai Peninsula, Alaska. Forest Ecology and Management 255:3571-3579.

Boggs, K., T. Kuo, and M. L. McTeague. 2011. Mosaicked landcover map for the Seward Peninsula - Nulato Hills - Kotzebue Lowlands Rapid Ecoregional Assessment study area. Alaska Natural Heritage Program, University of Alaska, Anchorage.

Bordage, D., and J. L. Savard. 1995. Black Scoter (*Melanitta nigra*). No. 177 in: A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, DC.

Bothwell, M. L., D. R. Lynch, H. Wright, and J. Deniseger. 2009. On the boots of fishermen: The history of didymo blooms on Vancouver Island, British Columbia. Fisheries 34:382-388.

Broennimann, O., U. A. Treier, H. Muller-Scharer, W. Thuiller, A. T. Peterson, and A. Guisan. 2007. Evidence of climatic niche shift during biological invasion. Ecological Letters 10:701-709.

Brown, C. L, J. Burr, K. Elkin, and R. J. Walker. 2005. Contemporary subsistence uses and population: Distribution of non-salmon fish in Grayling, Anvik, Shageluk, and Holy Cross. Technical paper 289. Alaska Department of Fish and Game, Juneau.

Brown, J., and R. A. Kreig. 1983.Guidebook to permafrost and related features along the Elliot and Dalton highways, Fox to Prudhoe Bay, Alaska. Proceedings of Fourth International Conference on Permafrost. 18-22 July 1983. University of Alaska, Fairbanks, Alaska Division of Geological and Geophysical Surveys, 230 pp.

Brown, J., O. J. Ferrians, Jr., J. A. Heginbottom, and E. S. Melnikov. 1997. Circum-Arctic map of permafrost and ground-ice conditions. U.S. Geological Survey, Washington, DC. Map CP-45.

Brown, M. T., and M. B. Vivas. 2005. Landscape development intensity index. Environmental Monitoring and Assessment 101:289-309.

Brubaker, M. 2011. Climate change in Kivalina, Alaska. Alaska Native Tribal Health Consortium (ANTHC), Anchorage. January.

Brubaker, M., P. Chavan, J. Berner, M. Black, and J. Warren. 2012. Climate change in Selawik Alaska. Alaska Native Tribal Health Consortium (ANTHC), Anchorage.May.

Bryant, M. D., N. D. Zymonas, and B. E. Wright. 2004. Salmonids on the fringe: Abundance, species composition, and habitat use of salmonids in high-gradient headwater streams, Southeast Alaska. Transactions of the American Fisheries Society 133:1529-1538.

Buckwalter, J. D., J. M. Kirsch, and D. J. Reed. 2010. Fish inventory and anadromous cataloging in the Lower Yukon River Drainage, 2008. Fishery Data Series No. 10-76. Alaska Department of Fish and Game, Anchorage. 603 pp.

Burch, E. S., Jr. 1999. Caribou management in northwest Alaska. Unpublished paper.

Burn, C. R., and C. A. S. Smith. 1988. Observations of the 'thermal offset' in near-surface MAGTs at several sites near Mayo, Yukon Territory, Canada. Arctic 41(2):99-104.

Callaghan,T. V., M. Johansson, R. D. Brown, P. Y. Groisman, N. Labba, V. Radionov, R. S. Bradley, S. Blangy, O. N. Bulygina, T. R. Christensen, J. E. Colman, R. L. H. Essery, B. C. Forbes, M. C. Forchhammer, V. N. Golubev, R. E. Honrath, G. P. Juday, A. V. Meshcherskaya, G. K. Phoenix, J. Pomeroy, A. Rautio, D. A. Robinson, N. M. Schmidt, M. C. Serreze, V. P. Shevchenko, A. I. Shiklomanov, A. B. Shmakin, P. Skold, M. Sturm, M. Woo, and E. F. Wood. 2011. Multiple effects of changes in Arctic snow cover. Ambio 40:32-45. (doi:10.1007/s13280-011-0213-x)

Callaway, D., K. R. Criddle, E. and Shea. 1998. Subsistence fisheries. Pages 95-104 in: Implications of global change in Alaska and the Bering Sea region. Proceedings of a workshop at the University of Alaska, Fairbanks.

Carlson, M. L., and M. Shephard. 2007. The spread of invasive exotic plants in Alaska: Is establishment of exotics accelerating? In: T. B. Harrington and S. H. Reichard, technical editors. Meeting the Challenge: Invasive Plants in Pacific Northwestern Ecosystems. General Technical Report PNW-GTR-694. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Carlson, M. L., I. V. Lapina, M. Shephard, J. S. Conn, R. Densmore, P. Spencer, J. Heys, J. Riley, and J. Nielsen. 2008. Invasiveness ranking system for non-native plants of Alaska. General Technical Report R10-TP-143. USDA Forest Service, Alaska Region. 218 pp. Available on-line at www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_037575.pdf.

Chambers, M., D. White, R. Busey, L. Hinzman, L. Alessa, and A. Kliskey. 2007. Potential impacts of a changing Arctic on community water sources on the Seward Peninsula, Alaska. Journal of Geophysical Research-Biogeosciences 112:G04S52. (doi:10.1029/2006JG000351)

Chapin, F. S., M. W. Oswood, K. Van Cleve, L. A. Viereck, and D. L. Verblya, editors. 2006. Alaska's changing boreal forest. Oxford University Press, NY. 354 pp.

Chapin, F. S., III, T. S. Rupp, A. M. Starfield, L. DeWilde, E. S. Zavaleta, N. Fresco, J. Henkelman, and A. D. McGuire. 2003: Planning for resilience: Modeling change in human-fire interactions in the Alaskan boreal forest. Frontiers in Ecology and the Environment 1:255-261.

Chapin, F. S., III, M. Sturm, M. C. Serreze, J. P. McFadden, J. R. Key, A. H. Lloyd, A. D. McGuire, T. S. Rupp, A. H. Lynch, J. P. Schimel, J. Beringer, W. L. Chapman, H. E. Epstein, E. S. Euskirchen, L. D. Hinzman, G. Jia, C.-L. Ping, K. D. Tape, C. D. C. Thompson, D. A. Walker, and J. M. Welker. 2005. Role of land-surface changes in Arctic summer warming. Science 310(5748):657-660.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder, CO

Comer, P. J., and J. Hak. 2012. Landscape condition in the Conterminous United States. Spatial model summary. NatureServe, Boulder, CO.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, VA.

Conger, A. O., and J. Magdanz. 1990. The harvest of wildlife in three Alaska communities: Golovin, Brevig Mission and Shishmaref. ADFG technical paper 188.

Conn, J., K. Beattie, M. Shephard, M. L. Carlson, I. V. Lapina, M. Hebert, R. Gronquist, and M. Rasy. 2008. Alaska *Melilotus* (Fabaceae) invasions: Distribution, origin, and susceptibility of plant communities. Arctic, Antarctic, and Alpine Research 40:298-308.

Cornell, S., and J. P. Kalt. 2003. Alaska Native self-government and service delivery: What works? Udall Center for Studies in Public Policy, The University of Arizona, Tucson. June.

Cornish, B. J., and D. L. Dickson. 1997. Common Eiders nesting in the western Canadian Arctic. Pages 40-50 in: D. L. Dickson, editor. King and Common eiders of the western Canadian Arctic. Canadian Wildlife Service Occasional Paper No. 94.

Coxson, D. S., and J. Marsh. 2001. Lichen chronosequence (postfire and postharvest) in lodgepole pine (*Pinus contorta*) forests of northern interior British Columbia. Canadian Journal of Forest Research 79:1449-1464.

Cramp, S., and K. E. L. Simmons, editors. 1983. The birds of the Western Palearctic. Volume 3: Waders to gulls. Oxford University Press, Oxford.

Cruikshank, J. 1998. The social life of stories: Narrative and knowledge in the Yukon Territory. University of Nebraska Press, Lincoln.

Cutler, D. R., T. C. Edwards, K. H. Beard, A. Cutler, K. T. Hess, J. Gibson, and J. J. Lawler. 2007. Random forests for classification in ecology. Ecology 88:2783-2792.

Daanen, R. P., T. Ingeman-Nielsen, S. Marchenko, V. E. Romanovsky, N. N. Foged, M. Stendel, J. H. Christensen, and K. Hornbech Svendsen. 2011. Permafrost degradation risk zone assessment using simulation models. Cryosphere 5(4):1043-1056.

Day, R. H. 1995. New information on Kittlitz's Murrelet nests. Condor 97:271-273.

Day, R. H., K. L. Oakley, and D. R. Barnard. 1983. Nest sites and eggs of Kittlitz's and Marbled Murrelets. Condor 85(3):265-273.

DCCED [Alaska Department of Commerce, Community, and Economic Development]. 2012. Current community conditions: Alaska fuel price report. Alaska Department of Commerce, Community, and Economic Development (DCCED), Division of Community and Regional Affairs (DCRA). July.

De'ath, G. 2011. Mvpart: Multivariate partitioning. R package version 1.4-0. http://CRAN.R-project.org/package=mvpart

DeMarban, A. 2012. Begich panel considers deep water port to support arctic shipping. Alaska Dispatch. April 9.

DeMarban, A. 2012. Dwindling students mean four more rural Alaska schools will close. Alaska Dispatch. April 10.

Densmore, R. V., and K. F. Karle. 2009. Flood effects on an Alaskan stream restoration project: The value of long-term monitoring. Journal of the American Water Resources Association 45:1424-1433.

Djokic, D. 2008. Comprehensive terrain preprocessing using Arc Hydro Tools. http://www.hydrosys.net/myplus/bbs/table/hydrosys_doc/upload/Comprehensive%20terrain%20preprocessing%20using%20Arc%20Hydro%20tools.pdf

Earnst, S. L. 2004. Status assessment and conservation plan for the Yellow-billed Loon (*Gavia adamsii*). Scientific Investigations Report 2004-5258. U.S. Geological Survey. 42 pp.

Eisenhauer, D. I., and C. M. Kirkpatrick. 1977. Ecology of the emperor goose in Alaska. Wildlife Monographs 57:1-62.

Elith, J., C. H. Graham, R. P. Anderson, M. Dudík, S. Ferrier, A. Guisan, R. J. Hijmans, F. Huettmann, J. R. Leathwick, and A. Lehmann. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29:129-151.

Elith, J., and J. Leathwick. 2009. Species distribution models: Ecological explanation and prediction across space and time. Annual Review Ecology Evolution and Systematics 40:677-697.

Elith, J., S. Phillips, T. Hastie, M. Dudík, Y. E. Chee, and C. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Ecology 45:1372-1381.

Elphick, C. S., and J. Klima. 2002. Hudsonian Godwit (*Limosa haemastica*). In: A. Poole and F. Gill, editors. The Birds of North America, No. 629. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, DC.

EPA [Environmental Protection Agency]. 1992. Site Visit Reports: Alaska Placer Mines. Technical Resource Document. Environmental Protection Agency. http://www.epa.gov/osw/nonhaz/industrial/special/mining/techdocs/placer.htm.

Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. 2006. Ecological Integrity Assessment and Performance Measures for Wetland Mitigation. Final Report to US EPA Office of Water and Wetlands. NatureServe, Arlington, VA.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2012. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part A. Ecological Integrity Assessment overview and field study in Michigan and Indiana. EPA/600/R-12/021a. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Fair, J. 2002. Status and significance of Yellow-billed Loon (*Gavia adamsii*) populations in Alaska. Report to The Wilderness Society and Trustees for Alaska. Anchorage, AK.

Feldman G. M., A. S. Tetelbaum, N. I. Shender, and R. I. Gavriliev. 1988. The guidebook for temperature regime forecast in Yakutia (in Russian), Yakutsk. 240 pp.

Flagstad, L., and H. Cortes-Burns. 2010. Tracking weeds along the Iditarod National Historic Trail. Report to Bureau of Land Management, Anchorage Field Office. Alaska Natural Heritage Program, University of Alaska, Anchorage, AK.

Fielding, A. H., and J. F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24:38-49.

Foote, J. M. 1983. Classification, description, and dynamics of plant communities after fire in the taiga of interior Alaska. Research Paper PNW-307. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 108 pp.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 8:629-644.

Fortin, M., S. Payette, and K. Marineau. 1999. Spatial vegetation diversity index along a postfire successional gradient in the northern boreal forest. Ecoscience 6:204-213.

Fox, S. 2002. These are things that are really happening: Inuit perspectives on the evidence and impacts of climate change in Nunavut. Pages 12-53 in: I. Krupnik and D. Jolly, editors. The Earth is faster now: Indigenous observations of arctic environmental change. Arctic Research Consortium of the United States, Fairbanks, AK.

Gallagher, T. J. 1988. Native participation in land management planning in Alaska. Arctic 41:91-99.

Gelbard, J. L., and J. Belnap. 2003. Roads as conduits for exotic plants in a semi-arid landscape. Conservation Biology 17:420-432.

George, J. C., H. P. Huntington, K. Brewster, H. Eicken, D. W. Norton, and R. Glenn. 2004. Observations on shorefast ice dynamics in arctic Alaska and the responses of the Iñupiat hunting community. Arctic 57:363-374.

Georgette, S. 2001. Brown bears on the northern Seward Peninsula, Alaska. Traditional knowledge and subsistence uses in Deering and Shishmaref. Technical paper 248. Alaska Department of Fish and Game, Juneau.

Georgette, S., and H. Loon. 1991. Subsistence hunting of Dahl sheep in northwest Alaska. Technical paper 209. Alaska Department of Fish and Game, Juneau.

Georgette, S., K. Persons, E. Shiedt, and S. Tahbone. 2004. Subsistence wildlife harvests in five Northwest Alaska communities, 2001-2003.Kawerak, Inc., Maniilaq Association, and Alaska Department of Fish and Game, Juneau.

Glesne, R. S. 1986. Lake fishery habitat survey and classification on interior Alaska national wildlife refuges, 1984 and 1985. USFWS Fairbanks Fishery Resources Project Report Number FY-86/87. 55 pp.

Goodrich, L. E. 1978. Some results of numerical study of ground thermal regime. Proceedings of the Third International Conference on Permafrost. National Research Council of Canada, Ottawa*,* volume1, 29-34.

Gotthardt, T. A., and K. M. Walton. 2011. Prioritizing the risk of invasive animal and aquatic invertebrate species in Alaska's national forests. Prepared for the USDA Forest Service, Alaska Region. Alaska Natural Heritage Program, University of Alaska, Anchorage. 109 pp.

Griggs, R. F. 1936. The vegetation of the Katmai District. Ecology 17(3):380-417.

Gross, J.E. 2003. Developing conceptual models for monitoring programs. On-line at http://science.nature.nps.gov/im/monitor/docs/Conceptual_Modelling.pdf.

Gucker, C. L. 2009. *Melilotus alba, M. officinalis*. In: Fire Effects Information System [Online]. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). [http://www.fs.fed.us/database/feis/] (Accessed 21 August 2012).

Haley, S., and D. Fisher. 2012. Shareholder employment at Red Dog Mine. Institute of Social and Economic Research, Anchorage. April.

Hamilton, L. C., C. L. Seyfrit, and C. Bellinger.1997. Environment and sex ratios among Alaska Natives: An historical perspective. Population and Environment: A Journal of Interdisciplinary Studies 18(3):283-299.

Handel, C. M., and C. P. Dau. 1988. Seasonal occurrence of migrant Whimbrels and Bristle-thighed Curlews on the Yukon-Kuskokwim delta, Alaska. Condor 90:782-790.

Hansen, A. J., R. L. Knight, J. M. Marzluff, S. Powell, K. Brown, P. H. Gude, and K. Jones. 2005. Impacts of exurban development on biodiversity: Patterns, mechanisms, and research needs. Ecological Applications 15:1893-1905.

Harrington, B. A. 2001. Red Knot (*Calidris canutus*). In: A. Poole and F. Gill, editors. The Birds of North America, No. 563. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, DC.

Harrison, C. 1978. A field guide to the nests, eggs and nestlings of North American birds. W. Collins Sons and Co., Cleveland, OH.

Haynes, J. L. 1993. Annual reestablishment of mosquitofish in Nebraska. Copeia 1983(1):232-235.

Heide-Jorgensen, M. P., K. L. Laidre, L. T Quakenbush, and J. J Citta. 2012. The Northwest Passage opens for bowhead whales. Biology Letters 8(2):270-273. (DOI:10.1098/rsbl.2011.0731)

Heinselman, M. L. 1978. Fire in wilderness ecosystems. In: J. C. Hendee, G. H. Stankey, and R. C. Lucas. Wilderness Management. USDA Forest Service, Miscellaneous Publication 1365.

Heinselman, M. L. 1981. Fire and succession in the conifer forests of northern North America. Pages 374-405 in: D. C. West, H. H. Shugart, and D. B. Botkin. Forest succession: Concepts and application. Springer-Verlag, New York.

Henshaw, F., and G. Parker. 1913. Surface water supply of Seward Peninsula, Alaska. Government Printing Office, Washington, DC.

Higuera, P. E., L. B. Brubaker, P. M. Anderson, T. A. Brown, A. T. Kennedy, and F. S. Hu. 2008. Frequent fires in ancient shrub tundra: Implications of paleorecords for arctic environmental change. PLoS ONE 3(3):e0001744. (doi:10.1371/journal.pone.0001744)

Higuera, P. E., L. B. Brubaker, P. M. Anderson, F. S. Hu, and T. A. Brown. 2009. Vegetation mediated the impacts of postglacial climate change on fire regimes in the south-central Brooks Range, Alaska. Ecological Monographs 79 (2):201-219

Holt, E. A., B. McCune, and P. Neitlich. 2008. Reindeer grazing and fire impacts on macrolichen communities of the Seward Peninsula, Alaska. The Bryologist 111:68-83.

Hopkins, D. M., R. Pratt, R. E. Nelson, and C. L. Powell, II. 1983. Glacial sequence, southwestern Seward Peninsula. Pages 45-50 in: R. M. Thorson and T. D. Hamilton, editors. Glaciation in Alaska, Extended Abstracts. University of Alaska Museum, Fairbanks.

Howe, L., and S. Martin. 2010. Demographic change, economic conditions, and subsistence salmon harvests in Alaska's Arctic Yukon Kuskokwim Region. Pages 433-462 in: C. C. Krueger and C. E. Zimmerman, editors. Pacific salmon, ecology and management of western Alaska's populations. American Fisheries Society, Symposium 70, Bethesda, MD.

Hughes, N. F. 1999. Population processes responsible for larger fish upstream distribution patterns of Arctic grayling (*Thymallus arcticus*) in interior Alaskan runoff rivers. Canadian Journal of Fisheries and Aquatic Sciences 56:2292-2299.

Hunter, M. L. 1990. Wildlife, forests, and forestry: principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs, NJ.

Huntington, H., and S. Fox. 2005. The changing Arctic: Indigenous perspectives. Pages 62-95 in: Arctic Climate Impact Assessment. Cambridge University Press, New York.

Huntington, H. P., S. F. Trainor, D. C. Natcher, O. H. Huntington, L. DeWilde, and F. S. Chapin, III. 2006. The significance of context in community-based research: Understanding discussions about wildfire in Huslia, Alaska. Ecology and Society 11:40. http://www.ecologyandsociety.org/vol11/iss1/art40/.

Jandt, R. R., K. Joly, C. R. Meyers, and C. Racine. 2008. Slow recovery of lichen on burned caribou winter range in Alaska tundra: Potential influences of climate warming and other disturbances. Arctic, Antarctic and Alpine Research 40:89-95.

Jenkins, R. E. 1976. Maintenance of natural diversity: Approach and recommendations. Pages 441-451 in: K. Sabol, editor. Transactions–Forty-first North American Wildlife and Natural Resources Conference. Washington, DC. March 21-25, 1976.

Jimenez-Valverde, A., and J. M. Lobo. 2006. The ghost of unbalanced species distribution data in geographical model predictions. Diversity and Distributions 12:521-524.

Jimenez-Valverde, A., and J. M. Lobo. 2007. Threshold criteria for conversion of probability of species presence to either-or presence-absence. Acta Oecologica 31:361-369.

Johnson, K. N., and M. Herring. 1999. Understanding bioregional assessments. In: K. N. Johnson, F. Swanson, M. Herring, and S. Greene, editors. Bioregional assessments: Science at the crossroads of management and policy. Island Press, Washington, DC.

Johnson, C. J., and M. P. Gillingham. 2008. Sensitivity of species-distribution models to error, bias, and model design: An application to resource selection functions for woodland caribou. Ecological Modelling 213:143-155.

Johnstone, J. F., T. S. Rupp, M. Olson, and D. Verbyla. 2011. Modeling impacts of fire severity on successional trajectories and future fire behavior in Alaskan boreal forests. Landscape Ecology 26(4):487-500.

Joly, K. 2011. Modeling influences on winter distribution of caribou in northwestern Alaska through use of satellite telemetry. Rangifer 31(2):75-85.

Joly, K., P. Bente, and J. Dau. 2007. Response of overwintering caribou to burned habitat in northwest Alaska. Arctic 60(4):401-410.

Joly, K., F. S. Chapin, III, and D. R. Klein. 2010. Winter habitat selection by caribou in relation to lichen abundance, wildfires, grazing, and landscape characteristics in northwest Alaska. Ecoscience 17(3):321-333.

Joly, K., R. R. Jandt, and D. R. Klein. 2009. Decrease of lichens in Arctic ecosystems: The role of wildfire, caribou, reindeer, competition and climate in north-western Alaska. Polar Research 28(3):433-442. (doi:10.1111/j.1751-8369.2009.00113.x)

Joly, K., D. R. Klein, D. L. Verbyla, T. S. Rupp, and F. S. Chapin, III. 2011. Linkages between large-scale climate patterns and the dynamics of Arctic caribou populations. Ecography 34:345-352.

Jones, B. M., G. Grosse, C. D. Arp, M. C. Jones, K. M. W. Anthony, and V. E. Romanovsky. 2011. Modern thermokarst lake dynamics in the continuous permafrost zone, northern Seward Peninsula, Alaska. Journal of Geophysical Research-Biogeosciences 116: G00M03. (doi:10.1029/2011JG001666).

Jorgenson, M. T., and T. E. Osterkamp. 2005. Response of boreal ecosystems to varying modes of permafrost degradation. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 35(9):2100-2111.

Jorgenson, M. T., J. E. Roth, M. Emers, W. A. Davis , S. F. Schlentner, and M. J. Macander, 2004. Landcover Mapping for Bering Land Bridge National Preserve and Cape Krusenstern National Monument, Northwestern Alaska. Natural Resource Technical Report NPS/ARCN/NRTR-2004/001. National Park Service, Fort Collins, CO.

Jorgenson, M. T., J. E. Roth, P. F. Miller, M. J. Macander, M. S. Duffy, A. F. Wells, G. V. Frost, and E. R. Pullman. 2009. An ecological land survey and landcover map of the arctic network. Natural Resource Technical Report NPS/ARCN/NRTR-2009/270. National Park Service, Fort Collins, CO.

Jorgenson, M. T., V. Romanovsky, J. Harden, Y. Shur, J. O'Donnell, E. A. G. Schuur, M. Kanevskiy, and S. Marchenko. 2010. Resilience and vulnerability of permafrost to climate change. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 40(7):1219-1236.

Karlstrom, T. N. V., and others. 1964. Surficial geology of Alaska. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-357, scale 1:584,000.

Kasischke, E., D.Williams, and D. Barry. 2002. Analysis of the patterns of large fires in the boreal forest region of Alaska. International Journal of Wildland Fire 11(2):131-144.

Kaufman, D. S., R. C. Walter, J. Brigham-Grette, and D. M. Kopkins. 1991. Middle Pleistocene age of the Nome River glaciation, northwestern Alaska. Quaternary Research 36:277-293.

Kershaw, K. A. 1978. The role of lichens in boreal tundra transition areas. The Bryologist 81:294-306.

Kershaw, K. A., and W. R. Rouse. 1971. Studies on lichen-dominated systems. Canadian Journal of Botany 49:1389-1410.

Kessel, B. 1989. Birds of the Seward Peninsula, Alaska: Their biogeography, seasonality, and natural history. University of Alaska Press. 330 pp.

Klingensmith, K. M., and K. Vancleve. 1993. Denitrification and nitrogen-fixation in floodplain successional soils along the Tanana River, interior Alaska. Canadian Journal of Forest Research 23:956-963.

Knick, S. T., and J. T. Rotenberry. 1995. Landscape characteristics of fragmented shrub steppe habitats and breeding passerine birds. Conservation Biology 9:1059-1071.

Knight, R. L., H. A. Knight, and R. J. Camp. 1993. Raven populations and land-use patterns in the Mojave Desert, California. Wildlife Society Bulletin 21:469-471.

Kochtubajda, B., W. R. Burrows, D. Green, A. Liu, K. R. Anderson, and D. McLennan. 2011. Exceptional cloud-to-ground lightning during an unusually warm summer in Yukon, Canada. Journal of Geophysical Research-Atmospheres 116: D21206. (doi:10.1029/2011JD016080).

Kofinas, G. 2002. Community contributions to ecological monitoring. Pages 54-91 in: I. Krupnik and D. Jolly, editors. The Earth is faster now. Arctic Research Consortium of the United States (ARCUS), Fairbanks, AK.

Kofinas, G. P., F. S. Chapin, III, S. B. BurnSilver, J. I. Schmidt, N. L. Fresco, K. Kielland, S. Martin, A. Springsteen, and T. S. Rupp. 2010. Resilience of Athabascan subsistence systems to interior Alaska's changing climate. Canadian Journal of Forestry 40:1347-1359.

Kofinas, G., G. Osherenko, D. Klein, and B. Forbes. 2000. Research planning in the face of change: The human role in reindeer/caribou systems. Polar Research 19(1):3-21.

Krupnik, I., and D. Jolly, editors. 2002. The Earth is faster now: Indigenous observations of arctic environmental change. Arctic Research Consortium of the United States (ARCUS), Fairbanks, AK.

Kruse, J. A. 1982.Subsistence and the North Slope Iñupiat: The effects of energy development. Man in the Arctic Program, Monograph No. 4. University of Alaska, Anchorage.

Kruse, J., and K. Foster. 1986. Changes in rural Alaska settlement patterns. Alaska Review of Social and Economic Conditions 23:1. University of Alaska, Anchorage, Institute of Social and Economic Research.

Kruse, J., B. Poppel, L. Abryutina, G. Duhaime, S. Martin, M. Poppel, M. Kruse, E. Ward, P. Cochran, and V. Hanna. 2008. Survey of living conditions in the Arctic (SliCA). Pages 107-134 in: V. Møller, D. Huschka and A. Michalos, editors. Barometers of quality of life around the globe how are we doing? Springer-Verlag, New York.

Kudryavtsev, V. A., editor. 1981. Permafrost (short edition) (in Russian). MSU Press. 240 pp.

Kudryavtsev, V. A., L. S. Garagula, K. A. Kondrat'yeva, and V. G. Melamed. 1974. *Osnovy merzlotnogo prognoza* (in Russian). MGU. 431 pp. [CRREL Translation: V. A. Kudryavtsev et al., Fundamentals of Frost Forecasting in Geological Engineering Investigations, CRREL Draft Translation 606, 1977, 489 pp.]

Lachenbruch, A. H. 1959. Periodic heat flow in a stratified medium with application to permafrost problems. U.S. Geological Survey Bulletin 1083-A. 36 pp.

Land Design North. 2003. Nome tourism study. Pages 6.1 to 6.20 in: Alaska Department of Transportation. Northwest Alaska transportation plan.

Lasley, S. 2011. Renewed focus on mineral-rich Ambler. Mining News 16:4. January. http://www.petroleumnews.com/miningnewsnorth/index.shtml

Lawler, J. P., S. D. Miller, D. M. Sanzone, J. Ver Hoef, and S. B. Young. 2009. Arctic Network vital signs monitoring plan. Natural Resource Report NPS/ARCN/NRR—2009/088. National Park Service, Fort Collins, CO.

Leu, M., S. E. Hanser, and S. T. Knick. 2008. The human footprint in the West: A large-scale analysis of anthropogenic impacts. Ecological Applications 18(5):1119-1139.

Liaw, A., and M. Wiener. 2002. Classification and regression by randomForest. R News 2(3):18-22.

Liu, C., P. M. Berry, T. P. Dawson, and R. G. Pearson. 2005. Selecting thresholds of occurrence in the prediction of species distributions. Ecography 28:385-393.

Lloyd, A. H., T. S. Rupp, C. L. Fastie, and A. M. Starfield. 2002. Patterns and dynamics of treeline advance on the Seward Peninsula, Alaska. Journal of Geophysical Research-Atmospheres 108(D2). (doi:10.1029/2001JD000852)

Lloyd, A. H., K. Yoshikawa, C. L. Fastie, L. Hinzman, and M. Fraver. 2003. Effects of permafrost degradation on woody vegetation at arctic treeline on the Seward Peninsula, Alaska. Permafrost and Periglacial Processes 14(2):93-101.

Lloyd, D. S., J. P. Koenings, and J. D. LaPerriere. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7:18-33.

Lobo, J. M., A. Baselga, J. Hortal, A. Jiménez-Valverde, and J. F. Gómez. 2007. How does the knowledge about the spatial distribution of Iberian dung beetle species accumulate over time? Diversity and Distributions 13:772-780.

Lowe, M. 2010. Contemporary rural-urban migration in Alaska. Alaska Journal of Anthropology 8:71-88.

Lynch, J. A., J. L. Hollis, and F. S. Hu. 2004. Climatic and landscape controls of the boreal forest fire regime: Holocene records from Alaska. Journal of Ecology 92(3):477-489.

Lyon, B., and R. Montgomerie. 1995. Snow bunting and McKay's bunting. In: A. Poole and F. Gill, editors. The Birds of North America, No. 198-199. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, DC. 28 pp.

MacDonald, S. O., and J. A. Cook. 2009. Recent mammals of Alaska. University of Alaska Press, Fairbanks.

Magdanz, J., and C. Utermohle. 1994. The subsistence salmon fishery in the Norton Sound, Port Clarence, and Kotzebue districts. Technical paper 237. Alaska Department of Fish and Game, Juneau.

Magdanz, J., C. Utermohle, and R. Wolfe. 2002. The production and distribution of wild food in Wales and Deering Alaska. Technical paper 259. Alaska Department of Fish and Game, Juneau.

Magdanz, J. S., E. Trigg, A. Ahmasuk, P. Nanouk, D. Koster, and K. R. Kamletz. 2005. Patterns and trends in subsistence salmon harvests: Norton Sound and Port Clarence 1994-2003. ADFG Technical Report 294.

Magdanz, J. S., N. S. Braem, B. C. Robbins, and D. S. Koster. 2010. Subsistence harvests in northwest Alaska: Kivalina and Noatak, 2007. Technical paper 354. Alaska Department of Fish and Game, Juneau.

Magdanz, J. S., R. J. Walker, and R. R. Paciorek. 2004. The subsistence harvests of wild foods by residents of Shungnak, Alaska 2002. Technical paper 279. Alaska Department of Fish and Game, Juneau.

Manel, S., H. C. Williams, and S. J. Ormerod. 2001. Evaluating presence-absence models in ecology: The need to account for prevalence. Journal of Applied Ecology 38:921-931.

Marchenko, S., and V. Romanovsky. 2007. Modeling the effect of organic layer and water content on permafrost dynamics in the Northern Hemisphere, Eos Trans. AGU 88(52), Fall Meeting Supplement, GC23A-0985

Marks, J. S., T. L. Tibbits, R. E. Gill, and B. J. McCaffery. 2002. Bristle-thighed Curlew (*Numenius tahitiensis*). In: A. Poole and F. Gill, editors. The Birds of North America, No. 705. The Birds of North America, Inc., Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Marmion, M., M. Parviainen, M. Luoto, R. K. Heikkinen, and W. Thuiller. 2009. Evaluation of consensus methods in predictive species distribution modelling. Diversity and Distributions 15:59-69.

Martin, S. 2005. Determinants of well-being In Iñupiat and Yupiit Eskimos: Do communities matter? Ph.D. dissertation. University of Texas, Dallas.

Martin, S. In press. Indigenous social adaptations in northern Alaska as a measure of resilience. Ecology and Society.

Martinez-Meyer, E. 2005. Climate change and biodiversity: Some considerations in forecasting shifts in species' potential distributions. Biodiversity Informatics 2(0).

Matthews, Jr., J. V. 1974. Quaternary environments at Cape Deceit (Seward Peninsula, Alaska): Evolution of a tundra ecosystem. Geological Society of America Bulletin 85:1353-1384.

McClory, J., and T. Gotthardt. 2008. Non-native and invasive animals of Alaska: A comprehensive list and select species status reports. Alaska Natural Heritage Program Report. 63 pp.

McCune, B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR. 300 pp.

McDowell Group. 2012. Alaska visitor statistics program VI. Summer 2011.

McNab, W. H., and P. E. Avers. 1994. Ecological subregions of the United States: Section descriptions. Ecosystem Management Report WO-WSA-5. USDA Forest Service, Washington, DC. 284 pp.

McNab, W. H., D. T. Cleland, J. A. Freeouf, J. E. Keys, Jr., G. J. Nowacki, and C. A. Carpenter, compilers. 2007. Description of ecological subregions: Sections of the conterminous United States [CD-ROM]. General Technical Report WO-76B. USDA Forest Service, Washington, DC. 80 pp.

Miller, T. P. 1973. Distribution and chemical analyses of thermal springs in Alaska. USGS Open File Report 73-187. 9 pp.

Morneau, C., and S. Payette. 1989. Postfire lichen-spruce woodland recovery at the limit of the boreal forest in northern Quebec. Canadian Journal of Botany 67:2770-2782.

Myers-Smith, I. H., J. W. Harden, M. Wilmking, C. C. Fuller, A. D. McGuire, and F. S. Chapin, III. 2008. Wetland succession in a permafrost collapse: Interactions between fire and thermokarst. Biogeosciences 5(5):1273-1286.

Nadasdy, P. 1999. The politics of TEK: Power and the 'integration' of knowledge. Arctic Anthropology 36:1-18.

Nagel, D. 2005. Procedure for generating stream gradient and contributing areas using NHD lines in a vector environment. http://www.fs.fed.us/rm/boise/research/gis/documents/ProcedureForGeneratingVectorNHDStreamGradientandCA.pdf

Nakashima, D. J. 1986. Inuit knowledge of the ecology of the Common Eider in north Quebec. Pages 102-113 in: A. Reed, editor. Eider ducks in Canada. Canadian Wildlife Service Report Seriers No. 47. Ottawa, ON.

NBII & ISSG [National Biological Information Infrastructure & IUCN/SSC Invasive Species Specialist Group]. 2005. Species record for *Myxobolus cerebralis* in the Global Invasive Species Database. Available at: http://www.issg.org/database/species/ecology.asp?fr=1&si=437 (Accessed 24 March 2012).

NBII & ISSG [National Biological Information Infrastructure & IUCN/SSC Invasive Species Specialist Group]. 2011. Species record for *Procambarus clarkii* in the Global Invasive Species Database. Available at: http://www.issg.org/database/species/ecology.asp?si=608&fr=1&sts=&lang=EN. (Accessed 24 March 2012).

Nicolson, C. R., A. M. Starfield, G. P. Kofinas, and J. A. Kruse. 2002. Ten heuristics for interdisciplinary modeling projects. Ecosystems 5:376-384.

North, M. R. 1994. Yellow-billed Loon (*Gavia adamsii*). In: A. Poole and F. Gill, editors. The Birds of North America, No. 121. The Birds of North America, Inc., Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Noss, R. F. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). Biological Conservation 41:11-37.

Nowacki, G., P. Spencer, M. Fleming, T. Brock, and T. Jorgenson. 2001. Unified ecoregions of Alaska: 2001. U.S. Geological Survey Open-File Report 02-297. 2 pp. plus map.

NRC [National Research Council]. 1999. The Community Development Quota program in Alaska. National Academy Press, Washington, DC.

NRCS [Natural Resource Conservation Service]. 1979. Exploratory soil survey of Alaska; STATSGO Publication. USDA Natural Resource Conservation Service, Forth Worth, TX.

NRCS [USDA Natural Resources Conservation Service]. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. 663 pp.

Omernik, J. M., and R. G. Bailey. 1997. Distinguishing between watersheds and ecoregions. Journal of the American Water Resources Association 33(5): 935-949.

Osterkamp, T. E., M. T. Jorgenson, E. A. G. Schuur, Y. L. Shur, M. Z. Kanevskiy, J. G. Vogel, and V. E. Tumskoy. 2009. Physical and ecological changes associated with warming permafrost and thermokarst in interior Alaska. Permafrost and Periglacial Processes 20(3):235-256.

Palmer, R. S., editor. 1976. Handbook of North American birds. Volume 2. Waterfowl (first part). Whistling ducks, swans, geese, shelducks, dabbling ducks. Yale University Press, New Haven. 521 pp.

Patterson, S. 2010. Alaska Forest Health Conditions in Alaska – 2009. General Technical Report R10-PR-21. USDA Forest Service, Alaska Region.

Pawlowski, B. 2011. Transport issues for development projects in Alaska's rural communities. Denali Commission. http://event.arc.nasa.gov/airships/sites/default/files/pdf/BobPawlowski.pdfhttp://event.arc.nasa.gov/airships/

Pegau, R. E. 1972. Caribou investigations-analysis of range. Pages 1-216 in: R. E. Pegau and J. E. Hemming, editors. Caribou report. Volume 12. Progress report. Federal Aid in Wildlife Restoration, Projects W-17-2 and W-17-3, Job 3.3R. Alaska Department of Fish and Game, Juneau.

Pentz, S. B., and R. A. Kostaschuk. 1999. Effect of placer mining on suspended sediment in reaches of sensitive fish habitat. Environmental Geology 37:78-89.

Petersen, M. R., J. A. Schmutz, and R. F. Rockwell. 1994. Emperor Goose (*Chen canagica*). In: A. Poole and F. Gill, editors. The Birds of North America, Vol. 3, No. 97. The Birds of North America, Inc., Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Pfister, C. A., S. J. McCoy, J. T. Wootton, P. A. Martin, A. S. Colman, and D. Archer. 2011. Rapid environmental change over the past decade revealed by isotopic analysis of the California Mussel in the Northeast Pacific. PLoS ONE 6(10):e25766. (doi:10.1371/journal.pone.0025766)

Pharand, D. 2007. The Arctic waters and the Northwest Passage: A final revisit. Ocean Development and International Law 38(1-2):3-69.

Phillips, S. J., and M. Dudik. 2008. Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation. Ecography 31:161-175.

Phillips, S. J., M. Dudik, and R. E. Schapire. 2004. A maximum entropy approach to species distribution modeling. Pages 655-662 in: Proceedings of the Twenty-First International Conference on Machine Learning.

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling 190:231-259.

Piatt, J. F., N. L. Naslund, and T. I. van Pelt. 1999. Discovery of a new Kittlitz's Murrelet nest: Clues to habitat selection and nest-site fidelity. Northwest Naturalist 80:8-13.

PADUS [Protected Areas Database of the United States]. 2011. Version 1.2, April 2011. http://gapanalysis.usgs.gov/padus/

R Development Core Team. 2005. R: A language and environment for statistical computing, reference index version 2.14.1. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, http://www.R-project.org.

Racine, C. H. 1979. Climate of the Chucki-Imuruk area. Pages 32-37 in: H. R. Melchior, editor. Biological Survey of the Bering Land Bridge National Monument. Alaska Cooperative Park Studies Unit, University of Alaska, Fairbanks.

Racine, C. H., W. A. Patterson, III, and J. G. Dennis. 1983. Permafrost thaw associated with tundra fires in northwest Alaska. Pages 1024-1029 in: Proceedings, Permafrost, Fourth International Conference. National Academy Press, Washington, DC.

Racine, C. H., L. A. Johnson, and L. A. Viereck. 1987. Patterns of vegetation recovery after tundra fires in northwestern Alaska, USA. Arctic and Alpine Research 19:461-469.

Rencz, A. N., and A. N. D. Auclair. 1978. Biomass distribution in a sub-arctic *Picea mariana-Cladonia alpestris* woodland. Canadian Journal of Forest Research 8:168-172.

Reynolds, J. B. 1985. Streamside bioassay of resident stream fishes, invertebrates, and algae in gold, placer mining effluent - interior Alaska. Progress report, July 15, 1985 - October 15, 1985. Research Work Order 14-16-009-1532 No. 5. Memorandum from University of Alaska to U.S. Fish and Wildlife Service dated October 25, 1985.

Riitters, K. H., and J. D. Wickham. 2003. How far to the nearest road? Frontiers in Ecology and the Environment 1:125-129.

Riordan, B., D. Verbyla, and A. D. McGuire. 2006. Shrinking ponds in subarctic Alaska based on 1950-2002 remotely sensed images. Journal of Geophysical Research 111:G04002. (doi:10.1029/2005JG000150)

Ritchie, R. J., A. M. Wildman, and C. M. White. 2004. Peregrine Falcons nesting on lake bluffs on the Arctic Coastal Plain of northern Alaska. Raptor Research 38:158-160.

Rocchio, F. J., and R. C. Crawford. 2011. Applying NatureServe's Ecological Integrity Assessment Methodology to Washington's Ecological Systems. Washington Natural Heritage Program, Washington Department of Natural Resources, Olympia, WA.

Romanovsky, V. E. 1987. Approximate calculation of the insulation effect of the snow cover. In *Geokriologicheskie Issledovania* (in Russian). MGU Press 23:145-157.

Romanovsky, V. E., and T. E. Osterkamp. 1995. Interannual variations of the thermal regime of the active layer and near-surface permafrost in Northern Alaska. Permafrost and Periglacial Processes 6(4):313-335.

Romanovsky, V. E., and T. E. Osterkamp. 1997. Thawing of the active layer on the coastal plain of the Alaskan Arctic. Permafrost and Periglacial Processes 8(1):1-22.

Rowe, J. S., J. L Bergsteinsson, G. A. Padbury, and R. Hermesh. 1974. Fire studies in the Mackenzie Valley. ALUR Report 73-74-61. Arctic Land Use Research Program, Department of Indian Affairs and Human Development, Ottawa, Canada. 123 pp.

Rupp, T. S., F. S. Chapin, III, and A. M. Starfield. 2000a. Response of subarctic vegetation to transient climatic change on the Seward Peninsula in northwest Alaska. Global Change Biology 6(5):541-555.

Rupp, T. S., F. S. Chapin, III, and A. M. Starfield. 2001: Modeling the influence of topographic barriers on treeline advance at the forest-tundra ecotone in northwestern Alaska. Climate Change 48:399-416.

Rupp, T. S., M. Olson, L. G. Adams, B. W. Dale, K. Joly, J. Henkelman, W. B. Collins, and A. M. Starfield. 2006. Simulating the influences of various fire regimes on caribou winter habitat. Ecological Applications 16(5):1730-1743.

Rupp, T. S., A. M. Starfield, and F. S. Chapin, III. 2000b. A frame-based spatially explicit model of subarctic vegetation response to climatic change: A comparison with a point model. Landscape Ecology 15:383-400.

Rupp, T. S., A. M. Starfield, F. S. Chapin, III, and P. Duffy. 2002. Modeling the impact of black spruce on the fire regime of Alaskan boreal forest. Climatic Change 55(1-2):213-233.

Rupp, T. S., X. Chen, and M. Olson. 2007. Sensitivity of simulated boreal fire dynamics to uncertainties in climate drivers. Earth Interactions 11(3):1-21.

Sanderson, E. W., M. Jaiteh, M. A. Levy, K. H. Redford, A. V. Wannebo, and G. Woolmer. 2002. The human footprint and the last wild. BioScience 52:891-904.

Sazonova, T. S., and V. E. Romanovsky. 2003. A model for regional-scale estimation of temporal and spatial variability of active layer thickness and mean annual ground temperatures. Permafrost and Periglacial Processes 14:125-139.

Schoof, R. 2012. Oil exploration in arctic waters. Anchorage Daily News. June 26. http://www.adn.com/2012/06/26/2520907/oil-exploration-in-arctic-waters.html#storylink=cpy

Seiler, A. 2001. Ecological Effects of Roads, A review. Introductory Research Essay No. 9. Department of Conservation Biology, Swedish University of Agricultural Science, Upsalla.

Silapaswan, C. S., D. L. Verbyla, and A. D. McGuire. 2001. Land cover change on the Seward Peninsula: The use of remote sensing to evaluate the potential influences of climate warming on historical vegetation dynamics. Canadian Journal of Remote Sensing 27(5):542-554.

Spaulding, S. A., and L. Elwell. 2007. Increase in nuisance blooms and geographic expansion of the freshwater diatom *Didymosphenia geminata*. U.S. Geological Survey Open-File Report 2007-1425. 38 pp.

Spellman, B. T., and T. Wurtz. 2010. Invasive sweetclover (*Melilotus alba*) impacts native seedling recruitment along floodplains of interior Alaska. Biological Invasions. Published online: January 6, 2011.

Stafford, J. M., G. Wendler, and J. Curtis. 2000. Temperature and precipitation of Alaska: 50 year trend analysis. Theoretical and Applied Climatology 67(1-2):33-44.

Stone, K. R. 2010. *Hieracium aurantiacum*. In: Fire Effects Information System [Online]. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). [http://www.fs.fed.us/database/feis/] (21 August 2012).

Stow, D., A. Petersen, A. Hope, R. Engstrom, and L. Coulter. 2007. Greenness trends of Arctic tundra vegetation in the 1990s: Comparison of two NDVI data sets from NOAA AVHRR systems. International Journal of Remote Sensing 28(21):4807-4822.

Strang, E., and D. White. 2004. Assessing long term domestic water needs in the Arctic. Proceedings of the American Society of Civil Engineers. World Water and Environmental Resources Congress 2005. http://ascelibrary.org/doi/abs/10.1061/40792%28173%29241.

Suydam, R. S. 2000. King Eider (*Somateria spectabilis*). In: A. Poole and F. Gill, editors. The Birds of North America, No. 491. The Birds of North America, Inc., Philadelphia, PA, and The American Ornithologists' Union, Washington, DC.

Swanson, D. K. 1996. Fruticose lichen distribution in the Kobuk Preserve Unit, Gates of the Arctic National Park. Technical Report AFA RNRlNRTR-96/28. National Park Service, Anchorage, AK.

Swanson, J. D., M. Schuman, and P. C. Scorup. 1985. Range survey of the Seward Peninsula Reindeer Ranges, Alaska. USDA Soil Conservation Service, Anchorage, AK.

Szymoniak, N., G. Fay, and A. Villalobos-Melendez. 2010. Components of Alaska fuel costs: An analysis of the market factors and characteristics that influence rural fuel prices. Institute of Social and Economic Research, Anchorage. February. http://www.iser.uaa.alaska.edu/publications.php

Tebaldi, C., J. M. Arblaster, and R. Knutti. 2011. Mapping model agreement on future climate projections. Geophysical Research Letters 38:L23701.

Tebaldi, C., and R. Knutti. 2007. The use of the multi-model ensemble in probabilistic climate projections. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 365(1857):2053-2075.

The Nature Conservancy Ecoregional Portfolio Sites, 1990s-2000. http://maps.tnc.org/files/metadata/ERA_STEWARD_TNC_Portfolio_Terr_Phase1.xml\.

Theobald, D. M. 2001. Land-use dynamics beyond the American urban fringe. Geographical Review 91(3):544-564.

Theobald, D. M. 2010. Estimating natural landscape changes from 1992 to 2030 in the conterminous US. Landscape Ecology 25:999-1011.

Thomas, B. I., D. J. Cook, E. Wolff, and W. H. Kerns. 1959. Placer-mining methods and costs in Alaska. U.S. Department of Commerce, Bureau of Mines.

Tivy, A., S. E. L. Howell, B. Alt, S. McCourt, R. Chagnon, G. Crocker, T. Carrieres, and J. J. Yackel. 2011. Trends and variability in summer sea ice cover in the Canadian Arctic based on the Canadian Ice Service Digital Archive, 1960-2008 and 1968-2008. Journal of Geophysical Research-Oceans 116:C06027. (doi:10.1029/2011JC007248).

Trombulak, S. C., and C. A. Frissel. 1999. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Trummer, L., and J. Kruse. 2006. Nome: Alder dieback and mortality/willow defoliation, July 22-24, 2006. Trip report on file with R-10 Forest Health Protection.

Unnasch, R. S., D. P. Braun, P. J. Comer, and G. E. Eckert. 2008. The Ecological Integrity Assessment Framework: A framework for assessing the ecological integrity of biological and ecological resources of the National Park System. Report to the National Park Service.

U.S. Arctic Research Commission. 2003. Climate change, permafrost, and impacts on civil infrastructure. Permafrost Task Force Report. December.

U.S. Census Bureau. 2011. Census 2010 summary file 1— Alaska.

USACE [U.S. Army Corp of Engineers]. 2009. Alaska baseline erosion assessment. Anchorage. March.

USGS [U.S. Geological Survey]. 2008. LANDFIRE 1.1.0 Existing Vegetation Type (EVT) layer. 2008 Refresh. U.S. Department of the Interior (USDI), Geological Survey [Online]. Available: http://landfire.cr.usgs.gov/viewer/ (Acquired: April 24, 2012).

USGS [U.S. Geological Survey]. 2006. National hydrography dataset. [http://nhd.usgs.gov/index.html]

Van Cleve, K., F. S. Chapin, III, C. T. Dryness, and L. A. Viereck. 1991. Element cycling in taiga forest: State-factor control. BioScience 41:78-88.

Viereck, L. A. 1983. The effects of fire in black spruce ecosystems of Alaska and northern Canada. Pages 201-220 in: R. W. Wein and D. A. MacLean, editors. The role of fire in northern circumpolar ecosystems. John Wiley & Sons Ltd., New York.

Viereck, L. A., K. Van Cleve, and C. T. Dyrness. 1986. Forest ecosystems in the Alaska Taiga. Pages 22-43 in: K. Van Cleve, F. S. Chapin, III, and P. W. Flanagan, et al., editors. Forest Ecosystems in the Alaskan taiga: A synthesis of structure and function. Springer-Verlag, New York.

Viereck, L. A., C. T. Dyrness, A. R. Batten, and K. J. Wenzlick. 1992. The Alaska vegetation classification. General Technical Report PNW-GTR286. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 278 pp.

WACH Working Group. 2003. Cooperative management plan. Western Arctic Caribou Herd Working Group.

Wagener, S. M., and J. D. LaPerriere. 1985. Effects of placer mining on the invertebrate communities of interior Alaska streams. Freshwater Biology 4(4):208-213.

Walker, C. W., S. Baird, R. King, and D. Whigham. 2007. Wetland geomorphic linkages to juvenile salmonids and macroinvertebrate communities in headwater streams of the Kenai Lowlands, Alaska. U.S. Environmental Protection Agency Wetland Program Development Grants Final Report. 83 pp.

Walker, D. A. 1996. Disturbance and recovery of arctic Alaskan vegetation. Pages 35-72 in: J. F. Reynolds and J. D. Tenhunen, editors. Landscape function and disturbance in arctic tundra. Ecological Studies Volume 120. Springer-Verlag, New York.

Walker, D. A., T. D. Hamilton, C. L. Ping, R. P. Daanen, and W. W. Streever. 1983. Dalton highway field trip guide for the ninth international conference on permafrost. A supplement to Guidebook 4, Guidebook to permafrost and related features along the Elliott and Dalton Highways, Fox to Prudhoe Bay, Alaska, Jerry Brown and R.A. Kreig, eds. Alaska Division of Geological and Geophysical Surveys for the Fourth International Conference on Permafrost.

Walsh, J. E., W. L. Chapman, V. Romanovsky, J. H. Christensen, and M. Stendel. 2008. Global climate model performance over Alaska and Greenland. Journal of Climate 21(23):6156-6174.

Walton, K. M., and T. A. Gotthardt. 2011. Norway rat species summary. Alaska Natural Heritage Program, University of Alaska, Anchorage.

Weber, P. 1986. Downstream effects of placer mining in the Birch Creek Basin, Alaska. Technical Report No. 86-7. Alaska Department of Fish and Game, Division of Habitat, Juneau.

Weidmer, M. 2011. Hierarchical analysis of headwater lotic fish species-environment relationships in northern Alaska, U.S.A. In prep.

Wein, R. W., and L. C. Bliss. 1973. Changes in arctic *Eriophorum* tussock communities following fire. Ecology 54:845-852.

Wheeler, B. K. 2003. Raptors of western North America. Princeton University Press, Princeton, NJ.

White, C. M., and R. W. Nelson. 1991. Hunting range and strategies in a tundra breeding Peregrine Falcon and Gyrfalcon observed from a helicopter. Journal of Raptor Research 25:49-62.

Williams, P. J. 1964. Unfrozen water content of frozen soils and soil moisture suction. Geotechnique 14(3):231-246.

Wolfe, R. J., C. L. Scott, W. E. Simeone, C. J. Utermohle, and M. C. Pete. 2009. The "super household" in Alaska Native subsistence economies. Research report.

Wolfe, R. J., and C. L. Scott. 2010. Continuity and change in salmon harvest patterns, Yukon River drainage, Alaska. Final Report for Study 07253. U.S. Fish and Wildlife Service. May.

Woodford, R. 2012. Alaska's largest caribou herd is declining. Alaska Fish and Wildlife News. June 1. http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=560.

WRCC [Western Regional Climate Center]. 2001. Alaska climate summaries. Western Regional Climate Center, Desert Research Institute, Reno, NV. http://www.wrcc.dri.edu/summary/Climsmak.html.

Yarie, J. 1983. Forest community classification of the Porcupine River drainage, interior Alaska, and its application to forest management. General Technical Report PNW-154. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 72 pp.

Yoshikawa, K., W. R. Bolton, V. E. Romanovsky, M. Fukuda, and L. D. Hinzman. 2002. Impacts of wildfire on the permafrost in the boreal forests of Interior Alaska. Journal of Geophysical Research 108(D1). (doi:10.1029/2001JD000438)

Zhang, X., Y. Sheng, J. Li, J. Wu, J. Chen, and Y. Cao. 2012. Changes of alpine ecosystem along the ground temperature of permafrost in the source region of Datong River in the Northeastern Qinghai-Tibet Plateau. Journal of Food Agriculture & Environment 10(1):970-976.

8 Acknowledgements

The SNK REA contracting team wishes to acknowledge the support from the Bureau of Land Management, making this REA possible. We also thank the multi-agency Assessment Management Team for their guidance throughout each phase of this effort, as well as the USGS peer review team. Our team comprised of NatureServe staff, the Alaska Natural Heritage Program, Scenarios Network for Alaska and Arctic Planning (SNAP, University of Alaska-Fairbanks), Institute of Social and Economic Research (ISER, University of Alaska-Anchorage), Geophysical Institute Permafrost Lab (GIPL, University of Alaska-Fairbanks), California Academy of Sciences, Dr. Healy Hamilton, and Stephanie Auer all provided unique and truly critical contributions to the development and implementation of this assessment.

9 Glossary

Active layer: In regions where permafrost is present, the active layer is the top layer of soil or substrate that thaws during summer and is frozen during winter

Areas of Critical Environmental Concern (ACEC): Areas within the public lands where special management attention is required to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources or other natural systems or processes, or to protect life and safety from natural hazards (FLPMA 1976).

Assessment Management Team (AMT): BLM's team that provides overall direction and guidance to the REA and makes decisions regarding ecoregional goals, resources of concern, conservation elements, change agents, management questions, tools, methodologies, models, and output work products. The team generally consists of State Resources Branch Managers from the ecoregion, a POC, and possibly agency partners.

Attribute: A defined characteristic of a geographic feature or entity.

Change Agent: An environmental phenomenon or human activity that can alter/influence the future status of resource condition. Some change agents (e.g., roads) are the result of direct human actions or influence. Others (e.g., climate change, wildland fire, or invasive species) may involve natural phenomena or be partially or indirectly related to human activities.

Coarse Filter: A focus of ecoregional analysis that is based upon conserving resource elements that occur at coarse scales, such as ecosystems, rather than upon finer scale elements, such as specific species. The concept behind a coarse filter approach is that preserving coarse-scale conservation elements will preserve elements occurring at finer spatial scales.

Community: Interacting assemblage of species that co-occur with some degree of predictability and consistency.

Conservation Element: A renewable resource object of high conservation interest often called a conservation target by others. For purposes of this TO, conservation elements will likely be types or categories of areas and/or resources including ecological communities or larger ecological assemblages.

Development: A type of change (change agent) resulting from urbanization, industrialization, transportation, mineral extraction, water development, or other non-agricultural/silvicultural human activities that occupy or fragment the landscape or that develops renewable or non-renewable resources.

Didymo: *Didymosphenia geminate*, a species of diatom considered to be a nuisance species

Ecological Integrity: The ability of an ecological system to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion.

Ecological Status: The condition of a criterion (biological or socio-economic resource values or conditions) within a geographic area (e.g., watershed, grid). A rating (e.g., low, medium, or high) or ranking (numeric) is assigned to specific criteria to describe status. The rating or ranking will be relative, either to the historical range of variability for that criterion (e.g., a wildland fire regime criterion) or relative to a time period when the criterion did not exist (e.g., an external partnerships/collaboration criterion). (also see *Status)*

Ecoregion: An ecological region or ecoregion is defined as an area with relative homogeneity in ecosystems. Ecoregions depict areas within which the mosaic of ecosystem components (biotic and abiotic as well as terrestrial and aquatic) differs from those of adjacent regions (Omernik and Bailey 1997).

Ecosystem: The interactions of communities of native fish, wildlife, and plants with the abiotic or physical environment.

Element Occurrence: A term used by Natural Heritage Programs. An element occurrence generally delineates the location and extent of a species population or ecological community stand, and represents the geo-referenced biological feature that is of conservation or management interest. Element occurrences are documented by voucher specimens (where appropriate) or other forms of observations. A single element occurrence may be documented by multiple specimens or observations taken from different parts of the same population, or from the same population over multiple years.

Extent: The total area under consideration for an ecoregional assessment. For the BLM, this is a CEC Level III ecoregion or combination of several such ecoregions plus the buffer area surrounding the ecoregion. See *grain*.

Fine Filter: A focus of ecoregional analyses that is based upon conserving resource elements that occur at fine scale, such as specific species. A fine-filter approach is often used in conjunction with a coarse-filter approach (i.e., a coarse-filter/fine-filter framework) because coarse filters do not always capture some concerns, such as when a T&E species is a conservation element.

Fire Regime: Description of the patterns of fire occurrences, frequency, size, severity, and sometimes vegetation and fire effects as well, in a given area or ecosystem. A fire regime is a generalization based on fire histories at individual sites. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval (NWCG 2006).

Fragmentation: The process of dividing habitats into smaller and smaller units until their utility as habitat is lost (BLM 1997).

Geographic Information System (GIS): A computer system designed to collect, manage, manipulate, analyze, and display spatially referenced data and associated attributes.

Grain: Grain is the spatial unit of analysis for ecoregional assessment and is the smallest area analyzed and used for regional planning purposes. The many data and model outputs incorporated into an ecoregional analysis are usually upscaled or downscaled to grain scale. The grain for ecoregional analysis may be a regular size and shape (e.g., square, hexagon) but also may be defined by a particular level of hydrologic unit or similar geographic feature.

Grid Cell: When used in reference to raster data, a grid cell is equivalent to a pixel (also see *pixel*). When a raster data layer is converted to a vector format, the pixels may instead be referred to as grid cells.

Habitat: A place where an animal or plant normally lives for a substantial part of its life, often characterized by dominant plant forms and/or physical characteristics (BLM 1990).

Heritage: See *Natural Heritage Program.*

Heritage Program: See *Natural Heritage Program.*

Holarctic: Relating to the biogeographic region that includes the northern parts of the Old and New Worlds, and that comprises the Nearctic and Palearctic regions.

Hydrologic Unit: An identified area of surface drainage within the U.S. system for cataloging drainage areas, which was developed in the mid-1970s under the sponsorship of the Water Resources Council and includes drainage-basin boundaries, codes, and names. The drainage areas are delineated to nest in a multilevel, hierarchical arrangement. The hydrologic unit hierarchical system has four levels and is the theoretical basis for further subdivisions that form the *watershed boundary dataset* 5th and 6th levels. (USGS 2009).

Indicator: Components of a system whose characteristics (e.g., presence or absence, quantity, distribution) are used as an index of an attribute (e.g., land health) that are too difficult, inconvenient, or expensive to measure (USDA et al. 2005).

Inductive Model: Geo-referenced observations (e.g., known observations of a given species) are combined with maps of potential explanatory variables (climate, elevation, landform, soil variables, etc.). Statistical relationships between dependent variables (observations) and independent explanatory variables are used to derive a new spatial model.

Invasive Species: Species that are not part of (if exotic non-natives), or are a minor component of (if native), an original community that have the potential to become a dominant or co-dominant species if their future establishment and growth are not actively controlled by management interventions, or that are classified as exotic or noxious under state or federal law. Species that become dominant for only one to several years (e.g. short-term response to drought or wildfire) are not invasives (Modified from BLM Handbook 1740-2, Integrated Vegetation Handbook).

Key Ecological Attribute: An attribute, feature, or process that defines and characterizes an ecological community or system or entity; in conjunction with other key ecological attributes, the condition or function of this attribute or process is considered critical to the integrity of the ecological community or system in question. In the BLM REAs, various analyses will be conducted to calculate scores or indexes indicating the status of key ecological attributes for various Conservation Elements (CEs).

Landscape Species: Biological species that use large, ecologically diverse areas and often have significant impacts on the structure and function of natural ecosystems (Redford et al. 2000).

Landscape Unit: Because an REA considers a variety of phenomena, there will be many phenomena and process (or intrinsic) grain sizes. These will necessarily be scaled to a uniform support unit, which herein is called a *landscape unit*. This landscape unit will be the analysis scale used for reporting and displaying ecoregional analyses.

Management Questions: Questions from decision-makers that usually identify problems and request how to fix or solve those problems.

Metadata: The description and documentation of the content, quality, condition, and other characteristics of geospatial data.

Model: Any representation, whether verbal, diagrammatic, or mathematical, of an object or phenomenon. Natural resource models typically characterize resource systems in terms of their status and change through time. Models imbed hypotheses about resource structures and functions, and they generate predictions about the effects of management actions. (Adaptive Management: DOI Technical Guide).

Native Plant and Animal Populations and Communities: Populations and communities of all species of plants and animals naturally occurring, other than as a result of an introduction, either presently or historically in an ecosystem (BLM Manual H-4180-1).

Native Species: Species that historically occurred or currently occur in a particular ecosystem and were not introduced (BLM 2007b).

Natural Community: An assemblage of organisms indigenous to an area that is characterized by distinct combinations of species occupying a common ecological zone and interacting with one another (BLM 2007b).

Natural Heritage Program: An agency or organization, usually based within a state or provincial natural resource agency, whose mission is to collect, document, and analyze data on the location and condition of biological and other natural features (such as geologic or aquatic features) of the state or province. These programs typically have particular responsibility for documenting **at-risk species and threatened ecosystems. (See natureserve.org/ for additional information on these programs.)**

Occurrence: See *Element Occurrence*.

Permafrost: A thick subsurface layer of soil that remains frozen throughout the year, occurring chiefly in polar regions.

Pixel: A pixel is a cell or spatial unit comprising a raster data layer; within a single raster data layer, the pixels are consistently sized; a common pixel size is 30 x 30 meters square. Pixels are usually referenced in relation to spatial data that are in raster format. In this REA, some pixels sizes included 30 x 30 m and 2 x 2 km (also see *Grid Cell*).

Population: Individuals of the same species that live, interact, and migrate through the same niche and habitat.

Rapid Ecoregional Assessment (REA): The methodology used by the BLM to assemble and synthesize that regional-scale resource information, which provides the fundamental knowledge base for devising regional resource goals, priorities, and focal areas, on a relatively short time frame (less than 2 years).

Rapid Ecoregional Assessment Work Plan (REAWP): The work plan (scope of services) that guides the Phase II Assessment component of a REA. This document fully establishes the design of the Phase II effort, and is essentially the 'blueprint' for that work effort and resulting products.

Resource Value: An ecological value, as opposed to a cultural value. Examples of resource values are those species, habitats, communities, features, functions, or services associated with areas with abundant native species and few non-natives, having intact, connected habitats, and that help maintain landscape hydrologic function. Resource values of concern to the BLM can be classified into three categories: native fish, wildlife, or plants of conservation concern; regionally-important terrestrial ecological features, functions, and services; and regionally-important aquatic ecological features, functions, and services.

Scale: Refers to the characteristic time or length of a process, observation, model, or analysis. ***Intrinsic scale*** refers to the scale at which a pattern or process actually operates. Because nature phenomena range over at least nine orders of magnitude, the intrinsic scale has wide variation. This is significant for ecoregional assessment, where multiple resources and their phenomena are being assessed. ***Observation scale***, often referred to as sampling or measurement scale, is the scale at which sampling is undertaken. Note that once data are observed at a particular scale, that scale becomes the limit of analysis, not the phenomenon scale. ***Analysis*** or ***modeling scale*** refers to the resolution and extent in space and time of statistical analyses or simulation modeling. ***Policy scale*** is the scale at which policies are implemented and is influenced by social, political, and economic policies.

Scaling: The transfer of information across spatial scales. ***Upscaling*** is the process of transferring information from a smaller to a larger scale. ***Downscaling*** is the process of transferring information to a smaller scale.

Status: The condition of a criterion (biological or socio-economic resource values or conditions) within a geographic area (e.g., watershed, grid). A rating (e.g., low, medium, or high) or ranking (numeric) is assigned to specific criteria to describe status. The rating or ranking will be relative, either to the historical range of variability for that criterion (e.g., a wildland fire regime criterion) or relative to a time period when the criterion did not exist (e.g., an external partnerships/collaboration criterion).

Step-Down: A step-down is any action related to regionally-defined goals and priorities discussed in the REA that are acted upon through actions by specific State and/or Field Offices. These step-down actions can be additional inventory, a finer-grained analysis, or a specific management activity.

Stressor: A factor causing negative impacts to the biological health or ecological integrity of a Conservation Element. Factors causing such impacts may or may not have anthropogenic origins. In the context of the REAs, these factors are generally anthropogenic in origin.

Subwatershed: A subdivision of a *watershed*. A *subwatershed* is the 6th-level, 12-digit unit and smallest of the hydrologic unit hierarchy. Subwatersheds generally range in size from 10,000 to 40,000 acres. (USGS 2009).

Talik: A Russian term applied to permanently unfrozen ground in regions of permafrost; usually applies to a layer which lies above the permafrost but below the active layer, that is, when the permafrost table is deeper than the depth reached by winter freezing from the surface.

Terricolous: Living on or in the ground; used in this report in relation to lichens

Thermokarst: A land surface characterized by very irregular surfaces of marshy hollows and small hummocks formed as ice-rich permafrost thaws, that occurs in Arctic areas.

Value: See *resource value*.

Watershed: A watershed is the 5th-level, 10-digit unit of the hydrologic unit hierarchy. Watersheds range in size from 40,000 to 250,000 acres. Also used as a generic term representing a drainage basin or combination of hydrologic units of any size. (USGS 2009).

Watershed Boundary Dataset (WBD): A national geospatial database of drainage areas consisting of the 1st through 6th hierarchical hydrologic unit levels. The WBD is an ongoing multiagency effort to create hierarchical, and integrated hydrologic units across the Nation. (USGS 2009).

Wildland Fire: Any non-structure fire that occurs in the wildland. Three distinct types of wildland fire have been defined and include wildfire, wildland fire use, and prescribed fire (NWCG 2006).

10 List of Acronyms

AADT	Annual Average Daily Traffic
ACEC	Area of Critical Environmental Concern
ACS	American Community Survey
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADOT	Alaska Department of Transportation
AEA	Alaska Energy Authority
AFFID	Alaska Freshwater Fish Inventory Database
AEWC	Alaska Eskimo Whaling Commission
AkDoLWD	Alaska Department of Labor and Workforce Development
AKNHP	Alaska Natural Heritage Program
ALFRESCO	Alaska Frame-Based Ecosystem Code
ALT	Active Layer Thickness
AMT	Assessment Management Team
ANTHC	Alaska Native Tribal Health Consortium
AR4	International Panel on Climate Change - Fourth Assessment Report
AVHRR	Advanced Very High Resolution Radiometer
AWC	Anadromous Waters Catalog
AWS	Associate Weather Services
BEA	Bureau of Economic Analysis
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CA	Change Agent
CCVI	Climate Change Vulnerability Index
CE	Conservation Element
CVS	Conservation Value Summary
DCCED	Department of Commerce, Community, and Economic Development
DCRA	Division of Community and Regional Affairs
DEC	Department of Environmental Conservation
DEM	Digital Elevation Model
DNR	Alaska Department of Natural Resources
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EFC	Environmental Flow Components
EIA	Ecological Integrity Assessment
EIS	Environmental Impact Statement
EO	Element Occurrence
EPCA	Energy Policy and Conservation Act
ESA	Endangered Species Act
ESA	Ecological Status Assessment
ESD	Ecological Site Descriptions
ET	Evapotranspiration

FAO	Food and Agriculture Organization
FCC	Federal Communications Commission
FO	Field Office
FRI	Fire Return Interval
GA	Grazing Allotment
GASH	Grayling Anvik Shageluk Holy Cross
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamics Laboratory
GIPL	Geophysical Institute Permafrost Lab
GIS	Geographic Information System
GMU	Game Management Unit
HMA	Herd Management Area
HRV	Historic Range of Variation
HUC	Hydrologic Unit Code
HUD	Housing and Urban Development
IHS	Indian Health Service
IPCC	Intergovernmental Panel on Climate Change
ISER	Institute of Social and Economic Research
KEA	Key Ecological Attribute
LCM	Landscape Condition Model
LF	LANDFIRE (Landscape Fire and Resource Management Planning Tools)
LTK	Local and Traditional Knowledge
MAGT	Mean Annual Ground Temperature
MLRA	Multiple Resource Land Area
MQ	Management Question
MRDS	Mineral Resource Data System
NANA	Northwest Arctic Native Association
NCEP	National Centers for the Environmental Prediction
NHD	National Hydrological Dataset
NPMS	National Pipeline Mapping System
NPRB	North Pacific Research Board
NRCS	Natural Resource Conservation Service
NREL	National Renewable Energy Laboratory
NRV	Natural Range of Variability
NTAD	National Transportation Atlas Database
NWI	National Wetland Inventory
NWAB	Northwest Arctic Borough
ORV	Off-road Vehicle
PCE	Power Cost Equalization program
PFD	Permanent Fund Dividend
PRISM	Parameter-elevation Regressions on Independent Slopes Model
REA	Rapid Ecoregional Assessments
REAWP	Rapid Ecoregional Assessment Work Plan
RegCM	International Centre for Theoretical Physics Regional Climate Model
ROC	Receiver Operating Characteristic
SDM	Species Distribution Model

SNAP	Scenarios Network for Alaska and Arctic Planning
SNK	Seward Peninsula - Nulato Hills - Kotzebue Lowlands Ecoregion
SOW	Statement of Work (for REA contract)
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
SWAP	State Wildlife Action Plan
TEK	Traditional Ecological Knowledge
TWI	Topographic Wetness Index
USGS	United States Geological Survey
WACH	Western Arctic Caribou Herd

11 List of Appendices

(Appendices are provided as separate documents.)

Appendix A. CHANGE AGENTS
Appendix B. CONSERVATION ELEMENTS
Appendix C. PLACES
Appendix D. OTHER ASSESSMENTS
Appendix E. CONCEPTUAL MODELS FOR CONSERVATION ELEMENTS
Appendix F. COMMUNITY MEETINGS DETAILED SUMMAR